

Lincoln University Digital Dissertation

Copyright Statement

The digital copy of this dissertation is protected by the Copyright Act 1994 (New Zealand).

This dissertation may be consulted by you, provided you comply with the provisions of the Act and the following conditions of use:

- you will use the copy only for the purposes of research or private study
- you will recognise the author's right to be identified as the author of the dissertation and due acknowledgement will be made to the author where appropriate
- you will obtain the author's permission before publishing any material from the dissertation.

Otago Regional Council's Response to Lake Snow:
A Planner's Evaluation

A Dissertation
submitted in partial fulfilment
of the requirements for the Degree of
Master of Planning

at
Lincoln University
by
Stephanie Kay Dwyer

Lincoln University
2017

Abstract of a Dissertation submitted in partial fulfilment of the
requirements for the Degree of Master of Planning.

Otago Regional Council's response to lake snow:
A Planner's Evaluation

by

Stephanie Kay Dwyer

Invasive species are a threat to the economy, environment and community, therefore it is essential that there is an effective framework in place for biosecurity management in New Zealand, to ensure that planners within local authorities are able to competently respond to invasive species within their region. The main aim of this research was to identify potential 'implementation gaps' that influence the overall effectiveness of the biosecurity framework within the New Zealand context. Otago Regional Council's approach to lake snow (algae) will be used as case study. The Biosecurity Act (BSA) 1993 is an overarching statute responsible for restating rules and policies for exclusion, eradication and management of unwanted organisms. Under the BSA every local authority has the power to determine whether pests are unwanted organisms, and provide further surveillance of pests, and any action required to manage and control unwanted pest in the region.

This research argues that how an unwanted organism is framed can strongly influence how regional council's respond to an unwanted organism. Non-government organisations and freshwater scientists have framed lake snow as a biological risk at the earlier stages of detection, whereas Otago Regional Council was reluctant to frame lake snow as a biological incursion due to the lack of scientific evidence. Otago Regional Council's slow response allowed lake snow to rapidly spread through Lake Wanaka and, neighbouring lakes such as Lake Hawea and Wakatipu becoming unmanageable nuisance for communities, anglers, and recreationist. There is high uncertainty surrounding invasive pests in New Zealand, therefore, it is difficult to detect invasive pests and determine the effects that they may pose to the overall health of water users and water quality. To improve the overall effectiveness of regional planning under the Biosecurity Act 1993, it is recommended to increase the coordination and collaboration between government and non-governmental organisations, create precautionary invasive pests fund, , establish guidelines on identification pest, acknowledgement of uncertainties and risk of biological invasions, and lastly, develop an international database on invasive species,

where knowledge is shared. Further research on monitoring and identification technology, and understanding freshwater ecological natural systems is advised. The recommendations and future research are essential to improving the in implementation of a biosecurity framework within regional planning in New Zealand.

Keywords: Biosecurity, framing, lake snot/snow, Lake Wanaka, Ministry for Primary Industries, Otago Regional Council, risk, uncertainty

Acknowledgements

There is a various of people that I would like to acknowledge in this dissertation, without their much-needed help, support and guidance this dissertation would not have not completed. I would like to express my sincere gratitude to my supervisor, Ronlyn Duncan. Ronlyn has provided me with much needed advice, support and guidance throughout the dissertation process. Thank you Ronlyn, I wish you all the best for the future.

I would also like to thank Joan Gladwin from proper words in Christchurch, she has kindly copy edited my dissertation and worked with me towards producing dissertation that is clear, and consistent.

In addition, I would like to thank Don Robertson (Chairperson of Guardians of Lake Wanaka), Marc Schallenberg (freshwater scientist at Otago University, Phil Novis (Phycologist Research at Landcare) and Adam Uytendaal (freshwater scientist at Otago Regional Council) for their invaluable professional capacity and insight into the management of lake snow.

For all my friends and family, thank you for your ongoing support and encouragement especially in the last few months. Special thanks to Mandille Alcee.

It has worthwhile journey and I am grateful for the opportunity, skills and experiences I have learnt along the way. I am grateful to make it to the end. I am excited for the next chapter in my life.

Table of Contents

Abstract	ii
Acknowledgements	iv
List of Tables	vii
List of Figures	viii
Chapter 1 Introduction	1
1.1 Introduction	1
1.2 Case Study	2
1.3 Research Aims and Objectives	3
1.4 Research Structure	3
Chapter 2 Biosecurity Management Framework	4
2.1 Introduction	4
2.2 Resource Management Framework	4
2.3 Managing Biosecurity	5
2.4 New or Unwanted Organisms	7
2.5 Risk Analysis Framework	7
2.6 Conclusion	9
Chapter 3 Theoretical Framework	10
3.1 Introduction	10
3.2 Preventative and Precautionary Principles	10
3.3 Uncertainty	11
3.4 Framing	13
Chapter 4 Methods	15
4.1 Introduction	15
4.2 Case-Study Approach	15
4.3 Data Collection	15
4.3.1 Desk Top Study	16
4.3.2 Semi Structured Interviews	18
4.4 Limitations	19
4.5 Summary	19
Chapter 5 Results and Analysis	20
5.1 Introduction	20
5.2 Finding Lake Snow	20
5.3 Lake Snow Established in Lake Wanaka	20
5.4 The Spread of Lake Snow	23
5.5 2017 – Discovery of an Invasive Pest Research Priority	27
5.6 Summary	33

Chapter 6 Discussion.....	35
6.1 Reviewing the Shift in Frames and Framing of Lake Snow	35
6.2 Review of Institutional Arrangements and Challenges.....	38
6.3 Risk and Uncertainty	40
6.4 Implementation Gaps within the Biosecurity Framework.....	42
Chapter 7 Conclusion and Recommendations	44
7.1 Overview	44
7.2 Reappraisal of research aims and objectives.....	44
7.3 Conclusions	44
7.4 Recommendations	45
7.5 Further Research.....	46
Appendix A.....	47
Interview Questions	47
A.1 Adam Uytendaal, Freshwater Scientist at Otago Regional Council	47
A.2 Dr Don Robertson, Chairperson of Guardians of Lake Wanaka.....	47
Appendix B Letters	48
B.1 Letter to the Minister for the Environment.....	48
B.2 Letter to the Otago Daily Times.....	49
References	50

List of Tables

Table 4-1: Lake Snow Timeline from 2003 to 2017	16
Table 4-2: List of Interviews	18
Table 5-1 Otago Regional Council Priority Research question (Modified source: ORC, 2017a).	28
Table 5-2 Summary of perceptions and approaches taken towards lake snow 2003-2017	33

List of Figures

Figure 1-1 Lake snot from Lake Wanaka. (Source: Otago Regional Council, 2017).	2
Figure 2-1 Overview of resource management framework (Source: ORC, 2010)	4
Figure 2-2: Framework for managing and controlling biosecurity risk at different scales (Source: GIA, 2017)	5
Figure 2-3: Risk Analysis framework (Source: Biosecurity New Zealand, 2006, p. 11)	8
Figure 3-1: Wynne’s Framework of Uncertainty (Source: Wynne, 1992, p. 114)	12
<i>Figure 5-1: Photo of Marc Schallenberg (Source: Schallenberg, 2010)</i>	21
Figure 5-2: Sample of lake snow taken from lake Wanaka by Marc Schallenberg (Source: Schallenberg, 2010)	21
Figure 5-3: Pressure and responses diagram of Lake Wanaka (from Guardians of Lake Wanaka, 2013, p.5.)	23
Figure 5-4 Media articles on lake snow released in 2016	24
Figure 5-5: Lake snow/snot attached to a Wanaka water filter (source: Cook, 2016).	25
Figure 5-6 Results revealed from the genetic analysis on New Zealand and international lake snow samples A. Lake Coleridge, B. Lake Wānaka. C. Lake Wakatipu. D. Lake Youngs (WA, USA). E. Cultus Lake (Canada). F. Lac Léman (Switzerland). All shown at the same scale (the bar in E. is 10 µm).(source: Novis, Mitchell, & Podolyan, 2017).	31

Chapter 1

Introduction

1.1 Introduction

New Zealand's biodiversity is renowned as a unique attraction. For 80 million years, New Zealand has evolved in isolation, resulting in a biodiversity hotspot with many endemic species. Hence, New Zealand is more dependent on biosecurity measures compared with many other developed countries. Imported goods, mail and travellers (visitors and returning residents) are pathways for introducing pests, diseases, and other unwanted organisms into New Zealand. There has been an upsurge in the volume of goods crossing the New Zealand borders, between 2003 – 2014 the volume of mail parcels entering the country has increased by 216%, sea containers have increased by 37% and air passengers has increased by 47% (Ministry for Primary Industries, 2016a). New pests and diseases established in New Zealand can create risks for future exports, conservation tourism, agriculture production, health and safety and biodiversity. Therefore, biosecurity is strategically important and an issue of national security, to protect the sustainability of New Zealand's economy and ecology.

Biosecurity is the exclusion, eradication or effective management of risks posed by pests and diseases, to the economy, environment, and human health (Department of Conservation, 2016). The BSA and the Hazardous Substances and New Organisms Act (HSNO) 1996 were introduced in New Zealand to provide a policy and planning framework for managing and controlling biosecurity risks at the national and regional level. The Conservation Act 1987, Resource Management Act (RMA) 1991 and the Convention on Biological Diversity 1992 were introduced to protect and restore biodiversity through mitigating the effects of human activities on the environment (Goldson & Suckling, 2003).

The biosecurity framework and introduction of risk assessment of invasive species have contributed to increased knowledge about ecosystems, the establishment of pests, and improved methods of pest control. Although the development of science and policy motives has improved management and control of invasive species, it has become increasingly difficult to identify the risk that biosecurity poses and what it means for the future. The identification and assessment of a biosecurity risk is made more difficult by the different layers of uncertainty that are not well understood or acknowledged in biosecurity management under the BSA. It will be shown how conceptions of risk and uncertainty can affect how the biosecurity framework is implemented and integrated into regional council planning. How well New Zealand's biosecurity framework, embodied in the BSA, is integrated into regional planning in Otago, New Zealand will be the focus of this dissertation. Otago Regional Council's approach to lake snow will be used as a case study to evaluate the framework.

1.2 Case Study

Currently Otago Regional Council is addressing invasive gelatinous algae called “lake snow” that were introduced into Lake Wanaka in 2003. Lake snow is a sticky, biological material made up of groups of algae that form colonies. *Lindavia Intermedia* are the algae species responsible for producing lake snow (Otago Regional Council, 2017b) Lake snow can be characterised as a slow-forming and highly uncertain, complex issue in Otago. There is insufficient information and knowledge to identify what has influenced lake snow to form in other lakes in Central Otago. Lake snow gained the media’s attention in 2016 when it began to spread to other waterways and clog up drinking-water filters. Lake snow has remained dormant in Lake Wanaka since 200, and the media are asking the question “Why did Otago Regional Council take so long to address lake snow?” (Otago Regional Council, 2016).

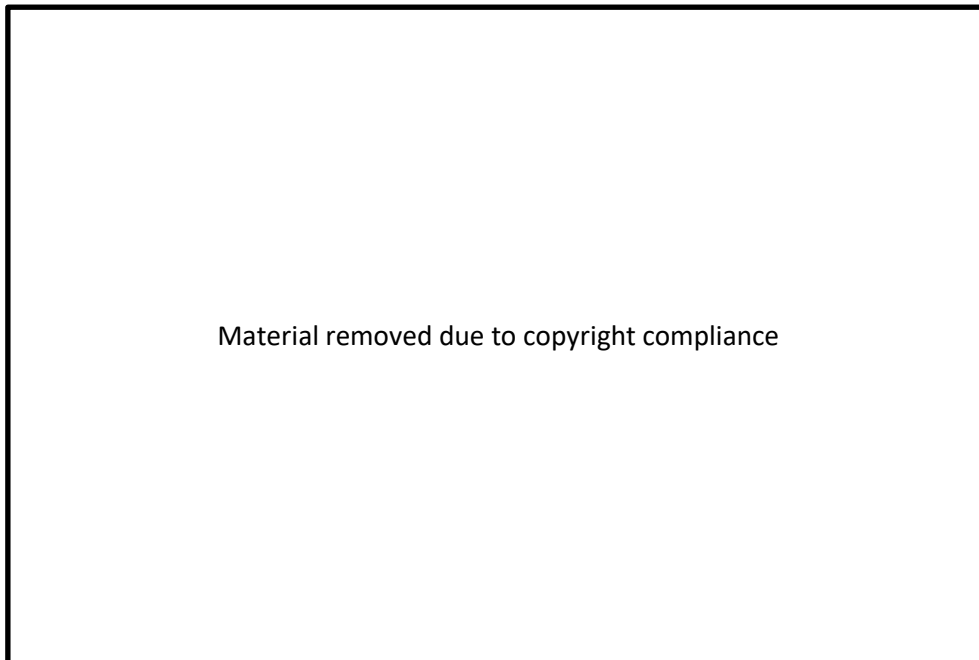


Figure 1-1 Lake snot from Lake Wanaka. (Source: Otago Regional Council, 2017).

1.3 Research Aims and Objectives

Despite New Zealand's commitment and planning system to manage and control invasive species, questions remain surrounding how the biosecurity framework is implemented into regional planning, to ensure that biological diversity, recreational enjoyment and the performance food production can be adequately protected. This research draws on a case study to examine the implementation of the biosecurity framework in regional planning specifically in the Otago region.

The main aim of this research was:

To identify potential 'implementation gaps' that influence the overall effectiveness of the biosecurity framework within the New Zealand context.

Case Study:

Otago Regional Council's response to 'lake snow' was used as a case study to focus the research.

The research aim was met by:

1. Investigating the shift in frames and framing of lake snow over time.
2. Reviewing the institutional arrangements and challenges.
3. Examining the risk and uncertainty of researching invasive species.
4. Making recommendations on how planners should deal with challenging biosecurity issues like lake snow.

1.4 Research Structure

This dissertation will analyse and compare how lake snow was originally framed by the Otago Regional Council, freshwater scientists, Guardians of Lake Wanaka and the Ministry for Primary Industries (MPI). How a problem is framed can often influence how institutions approach and resolve environmental issues (Bardwell, 1991). Understanding Otago Regional Council's approach under the biosecurity framework provides insight into how one regional council responds to complex, uncertain, slow-forming biosecurity risks and how such biosecurity should be managed by regional councils in New Zealand. To achieve the goal, this dissertation will consist of seven chapters. Chapter 1 provides the introduction, background and outline of this research. Chapter 2 will review the legislative biosecurity framework. Chapter 3 presents the conceptual framework with a review of literature that draws on ideas of risk and uncertainty. Chapter 4 explains the methodology of this research; Chapter 5 provides an analysis of the shift of frames; Chapter 6 discusses the findings with relevance to the theories and framework identified in Chapter 3. Lastly, Chapter 7 draws from the key theories and findings discussed in Chapter 6 to form conclusions and recommendations for future research to improve regional councils' responses to invasive species.

Chapter 2

Biosecurity Management Framework

2.1 Introduction

A management framework for the Biosecurity Act (BSA) 1993 guides how regional councils manage invasive species in New Zealand. This section reviews the resource management, biosecurity and risk analysis framework. A resource management framework identifies the relationship between the Resource Management Act 1991 and other legislation such as the BSA. The Biodiversity Act 1993 framework identifies the hierarchy for different levels of biosecurity management. Lastly, the risk analysis framework highlights the management of risk and uncertainty surrounding invasive species.

2.2 Resource Management Framework

The Resource Management Act (RMA) 1991 provides the overarching hierarchical framework for managing natural and physical resources at the national, regional, and local level in New Zealand. The resource management framework reflects the relationship between the RMA, various international agreements, and other legislation in New Zealand. There is additional legislation that may also have implications for the management of resources, such as the BSA and the Conservation Act 1987.

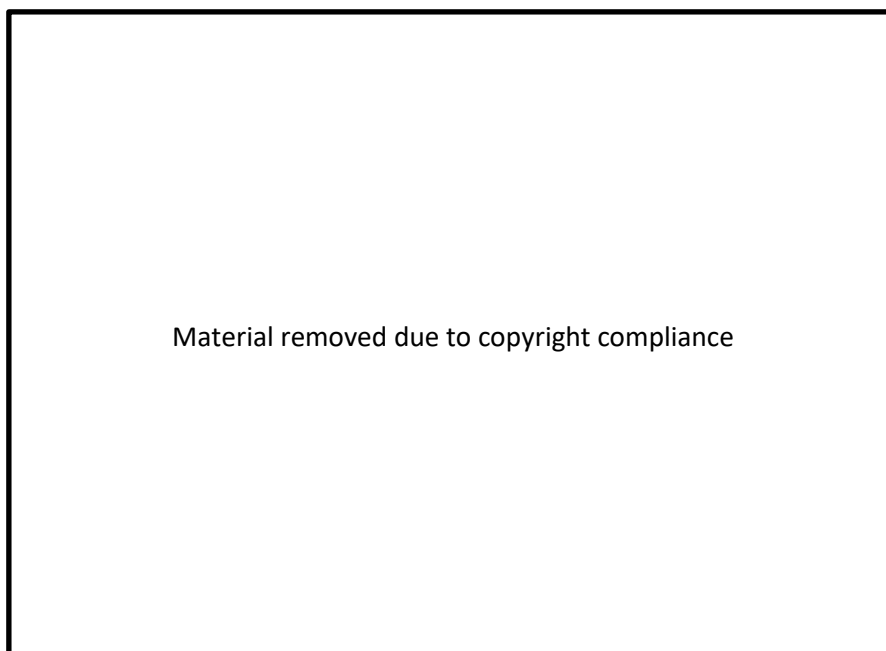


Figure 2-1 Overview of resource management framework (Source: ORC, 2010)

The Biosecurity Act 1993 falls under “other legislation” in Figure 2-1. The framework for biosecurity management is provided by the BSA and the HSNO, while mitigation of effects is an explicit obligation

of regulatory and management agencies under the Conservation Act, RMA and the Convention on Biological Diversity 1992 (Goldson & Suckling, 2003).

2.3 Managing Biosecurity

Ministry for Primary Industries (MPI) is the leading agency for managing biosecurity in New Zealand. MPI was formed in 2012 when the government departments Ministry of Agriculture and Forestry (Biosecurity New Zealand), Ministry of Fisheries and New Zealand Food Safety Authority merged. (Moir, 2017). However, the leading biosecurity agency may be dismantled into its individual components agriculture, forestry and fisheries by the newly formed Labour led government formed in October 2017 (Moir, 2017). Until that occurs MPI is responsible for prevention and management of risks from harmful organisms, such as pests and diseases through the administrating of the BSA (MPI, 2017b)

The BSA is the overarching statute governing the management of biosecurity risks in New Zealand (Parliamentary Commissioner for the Environment, 2002). The BSA was amended in 2012 to include a framework that enables government and industry to work together in partnership through a Government Industry Agreement (GIA) for biosecurity readiness and response. The GIA allows joint decisions and joint funding on biodiversity activities to ensure that the best possible outcomes for biosecurity management can be achieved (GIA, 2017). The biosecurity framework is demonstrated in Figure 2-2.



Figure 2-2: Framework for managing and controlling biosecurity risk at different scales (Source: GIA, 2017)

The biosecurity risk framework covers pre-border risk management, border management, readiness and response, and long-term pest management to ensure that biological risk and threats are managed throughout New Zealand. Pre-border management imposes health standards, risk assessments and international trade agreements to reduce risk of invasive pests coming into New Zealand. Border management, within the Ministry for Primary Industries (MPI), imposes biosecurity clearance at airports (e.g., sniffer dogs, main inspections and passenger inspections [MPI, 2017]). Pre-border and border stages of the framework are the strongest defence for biological invasion, because once invasive species come through the border and establish in New Zealand it becomes almost impossible to remove the unwanted organism.

Readiness and response actions deal with biosecurity emergencies. Agencies are given a wide range of powers (to enter properties, impose controls, destroy infected properties and give direction) to deal with harmful organisms once these pests get past the border (MPI, 2017). This stage can be effective, but it depends greatly on how long it takes the authorities to respond. The current funding arrangements for responding to biosecurity emergencies create uncertainties for the biosecurity agencies involved, as there are financial constraints that can affect how well other agencies can respond to biosecurity risks (Parliamentary Commissioner for the Environment, 2002), and finding the pest.

Biosecurity management deals with invasive species that spread both rapidly or gradually through the environment. Rapid onset disasters happen with no warning (e.g., floods, earthquakes, landslides; Reddish, 2015), whereas slow-onset disasters occur slowly, over a longer period (e.g., climate change, drought, loss of biodiversity; Siegele, 2012). Lake snow can be considered as a slow-onset disaster because it was introduced into Wanaka in 2003 but the effects were more noticeable in 2016 compared to the previous years, when the algae began to spread and establish in the surrounding lakes (Schallenberg, 2016). Both rapid and gradually established pests can potentially have damaging effects on communities, the environment and the economy in the long term (Siegele, 2012). Rapidly spread pests can be easily identified as a pest; however, slow-onset invasive pests can be difficult to find and identify, often by the time the pest has been found it becomes a matter of long-term management rather than an emergency response. The last line of defence is long-term pest management, that is, preparation and review of both national and pest-management strategies. The Ministry for Primary Industries is responsible for updating national plans and strategies. National Policy Direction for Pest Management was updated in 2015 and the National Biosecurity Strategy was updated in 2016. Regional councils are responsible for developing and implementing Regional Pest-Management Strategies (PMS) under the BSA, pest control carried out under this strategy must also comply with the regional and district plans under the RMA, as both plans may contain rules controlling the introduction,

spread and use of organisms; if it does not comply, a resource consent must be applied for (ORC, 2009). Overall, it has been estimated that regional councils spend \$40 million per year to manage and control “new organisms” and “unwanted organisms” that become established in New Zealand (MPI, 2017). Eradicating an established pest is extremely difficult, especially when there is uncertainty surrounding the establishment, eradication or the detection of the unwanted pest or new organism.

2.4 New or Unwanted Organisms

The BSA places a significant degree of decision-making in the hands of the Chief Technical Officers (CTOs). The BSA(s 101(1)) requires the Director-General of Agriculture and Forestry to appoint CTOs under the Act. Any department with biosecurity responsibility (including the Department of Conservation [DOC] and the Ministry for Primary Industries) has a CTO. CTOs are responsible for determining whether a new organism is an unwanted organism (Parliamentary Commissioner of Environment, 2002). The BSA also places a general duty on all persons in New Zealand to notify the CTO of the presence of unwanted organisms (Owens, n.d.). A new organism is identified under the HSNO Act as a pest or a disease that has newly invaded New Zealand, whereas MPI identify an unwanted organism as any organism that is capable of harming natural and physical resources (e.g., forests and waterways) or human health; this is not necessarily a new organism. Once the CTO has identified the unwanted organisms, they are placed on an Unwanted Organism Register. This on-line register is essential to ensuring that all regional councils in New Zealand have clarity about which organisms are unwanted. Regional councils are responsible for managing and controlling unwanted pests identified in the national register if they become established within their region (Teulon, Boyd Wilson, Holton and Ridley, n. d).

The BSA, HSNO and risk analysis framework each provide an essential role in combating the introduction of new organisms and managing the eradication of unwanted pests in New Zealand. In addition, risk analysis is used to provide recommendations on the likelihood of an organism entering, establishing or spreading in New Zealand, and the likely options available for managing the identified risk.

2.5 Risk Analysis Framework

In terms of biosecurity, risks are the likelihood of the occurrence and the magnitude of the consequences of an adverse event (Biosecurity New Zealand, 2006), the introduction of an obnoxious organism into New Zealand. In 2006 the original Biosecurity New Zealand developed a risk analysis framework under the World Organisation for Animal Health (OIE) and the International Plant Convention (IPC) to manage risk and uncertainty surrounding invasive species. There are three main risk analysis processes to support or inform the biosecurity risk management. The three processes

include: Import risk analysis, pest risk assessment and organism consequence assessment. Import risk analysis occurs at pre-border management, it involves identifying appropriate risk mitigating options to reduce pathways where organisms can enter the border through shipping, passengers or packaging, example importing fresh fruit for consumption may bring in unwanted pests that affect quality and overall production of New Zealand fruit. Pest risk assessment measures the potential risk of an organism being introduced into New Zealand, this occur at the border. This stage is used to inform biosecurity surveillance activities or identify pests of high risk to New Zealand. Lastly, organism consequence assessment measures the impact an established organism will have on the environment, economy and society in New Zealand.

OIE provides a chapter on risk in *Terrestrial Animal Health Code*, with guidelines for the placement of measures to prevent the introduction of organisms that have negative consequences on the environment (Biosecurity New Zealand, 2006). The IPC provides *The International Standards for Phytosanitary Measures* (ISPM) Nos. 2, 11 and 21, which together provide a risk analysis process that considers the risk of imported plants and diseases (Biosecurity New Zealand, 2006).

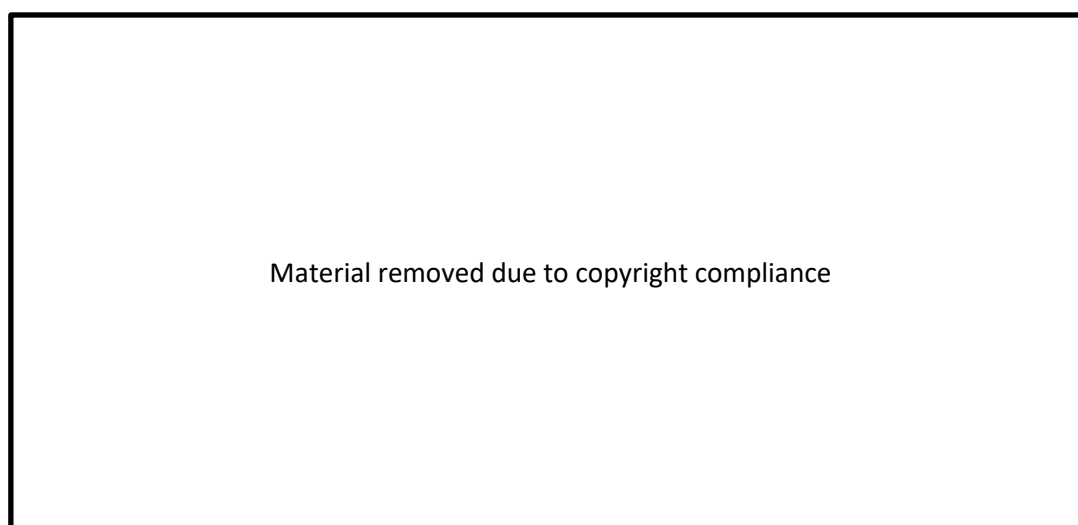


Figure 2-3: Risk Analysis framework (Source: Biosecurity New Zealand, 2006, p. 11)

There are four main stages in risk analysis: managing the project, hazard identification, risk assessment and management option evaluation. Each stage of this framework requires communication and documentation. Firstly, managing the project involves prioritisation, planning, scoping and a communication strategy. Prioritisation involves what risks should be managed and to what levels (Biosecurity New Zealand, 2006). Prioritisation is made necessary by insufficient resources being available to effectively manage all risks (Biosecurity New Zealand, 2006). Planning and scoping defines the overarching purpose of the project (e.g., roles, responsibilities and how to address the risk). This

stage takes into consideration the constraints, limitations, and what is not achievable. The Communication Strategy details how biosecurity incursions are going to be reported to stakeholders and decision makers (Biosecurity New Zealand, 2006). At this stage, communication about uncertainty and the limitations is essential, because it increases stakeholders' and decision makers' understanding of the complexities and challenges in risk assessment. It is expected that communication about uncertainty can lead to increased acceptance of results and decision-making (Biosecurity New Zealand, 2006).

Secondly, hazard identification is an essential step that must be conducted prior to risk assessments. This stage involves identifying the hazard/the unwanted organisms and the risks associated with entrance pathways or imported goods that could lead to the introduction of unwanted organisms. Thirdly, risk assessment evaluates the likelihood and environmental, economic and human health consequences of entry, exposure and establishment of potential hazard within New Zealand (Biosecurity New Zealand, 2006). This stage is vital to understanding and identifying risk, but it is extremely difficult to get right, especially considering that risk analysts assess risk with very little or insufficient information on the likelihood that species will arrive, establish and spread into new environments. Understanding these risks and consequences are often marked by profound uncertainties (Cook et al., 2012). This stage aims to identify and reduce uncertainties.

Lastly, the risk management option is the process of deciding upon biosecurity measures to effectively manage risks posed by unwanted organisms in New Zealand.

In biosecurity management, risk analysis is an essential tool aimed to inform pest eradication or management programmes that need to be developed by central and local government (Biosecurity New Zealand, 2006).

2.6 Conclusion

The biosecurity and risk analysis framework provides direction and guidance through the development of national policy and the regional pest-management strategies. The pre-border and border security measures are essential components of the biosecurity planning system. However, by the time invasive species have been incorporated into plans it is often too late. Invasive species have already become established in New Zealand and have resulted in negative consequences on the economic, social, cultural, and biophysical environment. This research will illustrate that it is extremely difficult to identify biological risks and threats under the biosecurity framework due to the uncertainty surrounding the establishment and spread of invasive species in New Zealand. In the next chapter, uncertainty and risk literature is explored. The biosecurity literature will be used to evaluate how well Otago Regional Council has responded to lake snow under the Biosecurity Act 1993 framework.

Chapter 3

Theoretical Framework

3.1 Introduction

Everyday activities involving travel, trade and commuting create pathways for introducing invasive pests into the country, and this has the potential to have undesirable environmental effects. Therefore, science has a crucial role in assessing and reducing the risk of invasive pests to society. Scientific advice can help decision makers identify, prioritise and guide decisions on the management of biosecurity threats (Parliamentary Commissioner for the Environment, 2002). However, there is considerable uncertainty and risk surrounding the introduction and establishment of invasive pests, making it difficult to effectively respond and eradicate invasive species.

This theoretical context will explore a variety of concepts and frameworks on risk and uncertainty that will provide insights for analysing Otago Regional Council's approach to lake snow and will also identify the challenges for one regional council of implementing the biosecurity risk framework under the Biosecurity Act 1993. Firstly, the preventative and precautionary principles and approaches that have evolved in decision-making in environmental policy will be explored. Secondly, the uncertainty framework devised by Wynne (1992) will be used to illustrate the different components of uncertainty. Lastly, the influence that framing can have on the management of uncertain biological threats and risks will be highlighted.

3.2 Preventative and Precautionary Principles

Risk assessment is a scientifically disciplined way of analysing risk and safety problems in society (Wynne, 1992). Risk assessment is often used by scientists in biosecurity management to identify biosecurity risks. Wynne (1992) believes that the shift towards preventative approaches has been one of the most important goals of environmental and technological policies to assess risk.

Wynne (1992) defines the preventative approach as a shift of attention from "end of pipe" to "upstream" decisions in environmental management. He notes that the precautionary principle seeks to prevent the environmental effects before they occur, and so it is about anticipating and predicting potential future environmental effects and how can they be reduced. The precautionary principle gives practical effect to the preventative philosophy. The precautionary principle was originally developed to be used in situations of potentially serious or irreversible threats to human health or the environment. In these situations, there is a need to act to reduce the potential hazards before there is

proof of harm, taking into account the likely costs, benefits and inaction (Parliamentary Commissioner of the Environment, 2002). Wynne argues that the precautionary approach involves much more than simply shifting the proof of harm (reducing the hazards); it also challenges the scientific paradigm and encourages other sources of knowledge to be used.

Shifting attention upstream using the preventative and precautionary approach requires anticipatory knowledge which has inherent limitations (Wynne, 1992). Anticipatory knowledge refers to assumptions, conclusions and predictions drawn from scientific evidence and knowledge about future expectations. It assumes that scientific methods can be used to study and understand complex systems and can contribute solutions to improve environmental concerns. However, Wynne argues that science can only define a risk, or uncertainties by artificially “freezing” a surrounding context, which may or may not represent reality. It is a reductionist approach that isolates the elements of the problems, such as improving border-focused screening technologies, or pest control through genetic modified systems. Wynne states that all knowledge is conditional upon a range of assumptions about how people, systems, technologies and organisations are expected to behave (which often inadvertently become embedded in science and policy) being shown as correct. Science does have the ability to identify the risk of invasive pests but there are limitations; it cannot identify which invasive pests will be a threat and whether they will become established in New Zealand. In this next section uncertainty will be explored in more detail.

3.3 Uncertainty

Uncertainty is not universally observed, known or measured, but it is subjectively interpreted by those who attempt to manage it. The first step is to accept the existence of uncertainty in everyday lives, in this case accepting that uncertainty exists in assessing the risk of invasive species. Uncertainty can create challenges in how scientific knowledge is used by policy makers to understand environmental matters such as biosecurity. Wynne (1992) states that using a precautionary approach to identify upstream effects presents a useful framework for understanding and distinguishing multiple layers of uncertainty: risk, uncertainty, ignorance and indeterminacy.

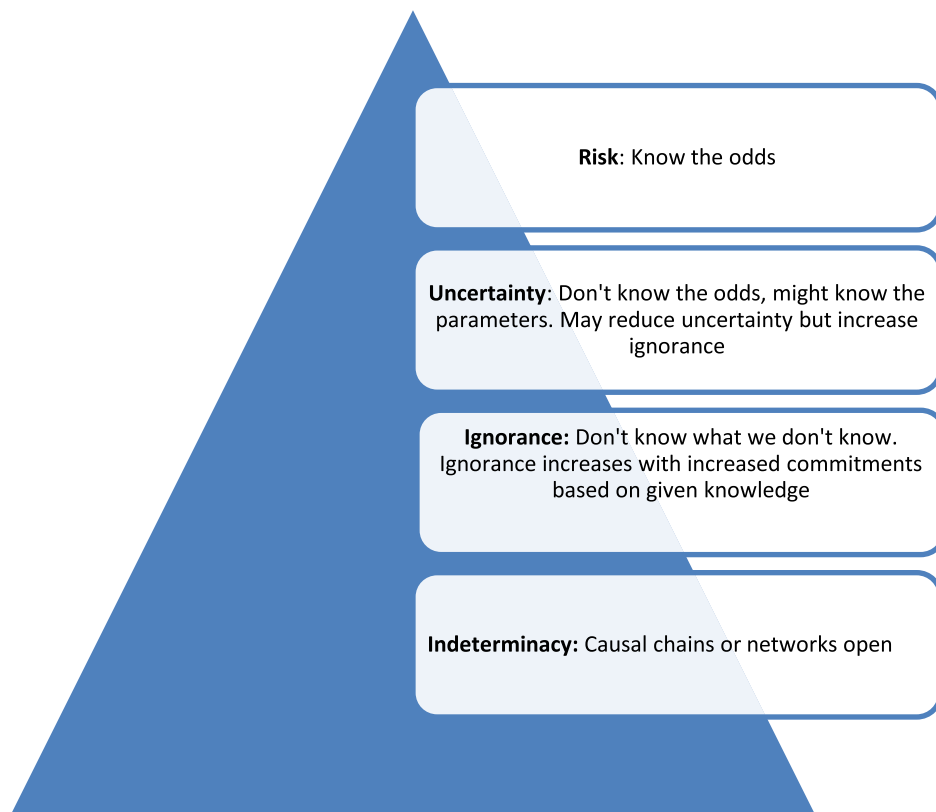


Figure 3-1: Wynne's Framework of Uncertainty (Source: Wynne, 1992, p. 114)

Wynne's first concept risk as identified in Figure 3-1 you may 'know the odds', this means that you can identify and quantify the probability of the outcome occurring, for example you can calculate the risk of invasive species being established in New Zealand. Wynne's second concept uncertainty refers to 'when the parameters are known but the odds are not'. This means the probability of the outcome occurring is uncertain. This type of uncertainty relates to epistemic uncertainty, which is derived from incomplete information and relates to how we know what we know. Uncertainty expands into ignorance and indeterminacy. Wynne's third concept ignorance is a far more difficult to identify and understand. Ignorance relates to ontology: 'we don't know what we don't know.' It forms a deep uncertainty that cannot be predicted or reduced by further research due to the complexity of the system. Whereas, Wynne's final concept indeterminacy is embedded into risk and uncertainty. Wynne (1992) refers to indeterminacy with regard to social institutions and practices. He argues that social institutions and practices either adapt scientific knowledge to fit into current paradigms in society, or social and technical situations are reshaped to validate the knowledge. There are gaps within scientific knowledge, social arrangements and interactions that attempt to reduce the gaps and form an understanding of the knowledge displayed by scientific research. However, in this process, conventional risk assessments tend to treat all uncertainties as if they were due to an incomplete definition of an essential determinate system. The misrepresentations of indeterminacies within

systems will prevent scientists and policy makers from understanding the system in any meaningful way due to the construction of social institutions and interactions.

Wynne argues that risk, uncertainty, and ignorance are overlaid on one another, the concepts are expressed depending on the scale of the social commitments, which have high reliance on the certainty of scientific knowledge being correct. Risk and uncertainty are within the abilities of scientific research to understand the natural variability that occurs within ecosystem services, whereas ignorance is beyond the limits of science, due to methodological, sociological and epistemological uncertainties; therefore, it cannot be reduced through scientific method. Methodological uncertainty relates to statistical and measurement errors that can affect the accuracy and reliability of scientific knowledge by either overestimating or underestimating the outcome of environmental matters (Peel, 2005). Sociological uncertainty relates to the diversification of knowledge across boundaries; it creates multiple knowledge's frames that can create conflicting beliefs and values about how a situation should be managed (Peel, 2005). How an issue or problem is framed and constructed by social institutions and practices can determine how it is approached but it prevents other ways of resolving the issue.

A precautionary approach exposes the different layers of uncertainty: risk, uncertainty, indeterminacy and ignorance in scientific knowledge. Biosecurity is reliant on risk assessment, which is a precautionary approach used to identify biological risk and reduce biological invasions in New Zealand. The risk assessment approach does create limitations in science's ability to show uncertainty, especially considering how the environmental risk is socially constructed. The construction and framing of risk can influence policy makers' approach to biosecurity threats in New Zealand. In the next section the theory surrounding framing will be explored.

3.4 Framing

Examining how a problem is defined and framed is essential for understanding how solutions have been formulated. Problem-framing guides the strategies and actions to address an environmental problem such as a biosecurity threat. The framing of current environmental or social issues involves defining what is at stake, who should be included in the decision-making process and in what role (Brugnach, M., Dewulf, A., Pahl-Wostl, C. and Taillieu, T, 2008). Problem definition reflects values and assumptions, determine strategies and profoundly impacts upon the quality of solutions (Bardwell, 1991).

To frame and define an issue requires building an understanding of the problem. A problem cannot be defined correctly if there is limited knowledge and understanding surrounding the topic. Bardwell

(1991) argues that organisations rely on familiarity in problem solving and problem definition. Organisations such as a council are likely to solve a problem by reflecting back on past experiences or similar situations. Unfortunately, this means that new problems may be cast as old ones and more effective options are often overlooked. With each option to resolve the identified environmental problem, comes a new array of problems that can potentially have long-term and irreversible impacts on the environment (Bardwell, 1991). There are challenges in framing environmental problems; the precautionary approach can be used in risk analysis to expose and eliminate factors of risk and uncertainty in problem definition and problem solving. For example, whether an organism found out of place in the environment is framed as invasive or not has social and economic implications under the biosecurity framework in New Zealand. The analytical framework provides understanding to how frames are formulated in society.

Analytical framework

Framing research has important roots in the work of cognitive biases and decision heuristics. Society constructs frames to understand the elements and processes of the external world. Frames and framing are constantly being used in the decision-making process. However, frames and framing of environmental matters can often create inconsistencies due to the underlying judgements: it lacks conceptual precision in its description of essential elements and processes (Dewulf et al., 2004). Dewulf et al. (2004) identify the nature of frames from a historical point of view that form two approaches—the interactional approach and the cognitive approach. The interactional approach resembles Bateson's (1954) work on metacommunication in which frames are treated as interactional alignments or co-constructions.

Frames are communication devices that individuals use to understand the interactions and negotiation between different parties; they can indicate how different groups can frame and perceive situations differently. In addition, in the cognitive frame theory approach formulated by Minsky (1975), frames are a cognitive representation that are stored in memory and then retrieved and applied to a new situation. This approach focuses on frames as knowledge structures that help to organise and interpret data that fits into current paradigms, beliefs and values of society. Cognitive and interactional approaches have been used in this research to identify how Otago Regional Council framed lake snow as an issue, and to understand how framing has shifted over time.

Chapter 4

Methods

4.1 Introduction

To address the research, aim and objectives and the issues identified in the theoretical context, a qualitative single case-study approach has been adopted. Data from a desk top study of planning instruments and semi interviews techniques were triangulated and formed the basis of the case study. These methods are described in more detail in this chapter.

4.2 Case-Study Approach

Yin (2013) proclaims case-study research is especially useful for apprehending complex contemporary issues where an in-depth understanding of an issue is preferable to breadth. A case-study method enables a researcher to closely examine the data. Yin (2013) uses a twofold definition to describe the case-study research method. A case study is an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-world context. This is particularly useful when the boundaries between the phenomenon and context are not clear. Since the case-study method receives criticism in terms of lack of robustness as a research tool, developing the research design is crucial. Researchers can adopt either a single case or a multiple case design, depending on the issues in question.

For the purpose of this dissertation, an in-depth single case study has been used in this particular scenario. The single case study has provided a systematic way of observing the management processes used by one regional council over a long period of time. Single case-study research can make a significant contribution to knowledge and theory-building by confirming, challenging, or extending the theory and understanding of the context (Yin, 2013). The study will help to refocus future investigations into the introduction of invasive pests in New Zealand. However, the drawback of a single case design is its inability to provide a generalising conclusion, in particular when events are rare. The data-collection process involved triangulating the data with other methods to confirm the validity and reliability of the information.

4.3 Data Collection

Triangulation is a method used in qualitative research that involves cross-checking multiple sources and collection procedures to evaluate the extent to which all evidence converges and corroborates to reach the same finding (Yin, 2013). By developing convergent evidence, data triangulation helps to strengthen the validity of this case study. The use of multiple sources of data has provided multiple

measures of the same phenomenon and has allowed the researcher to address a broader range of historical and behavioural issues. Having multiple sources of data has increased the accuracy, precision, and certainty of the case study. Desk top study and semi-structured involved were used with the triangulation method to construct the case study.

4.3.1 Desk Top Study

Secondary data was gathered from an initial internet search of local, regional councils and biosecurity in New Zealand. Using the combined key words of “Otago Regional Council”, “Ministry for Primary Industries”, “Biosecurity Procedures”, “lake snow”, an internet scan of media sources, websites, journal articles, scientific reports, and policy plans (council regional policy statements, national planning documents), pest management strategies legislation (biosecurity framework) and council’s minutes was undertaken to find range useful and appropriate documents that can be used and analysed

The documents were examined using a document analysis. The document analysis served two purposes. The first was to clarify the development of the Biosecurity Act 1993 in order to understand the process and how one regional council implements the legislation. Secondly, it has allowed the evaluation of Otago Regional Council’s approach to lake snow under the biosecurity framework. The documents were drawn together and organised in a timeline from 2003 to 2017 (Table 4-1).

Table 4-1: Lake Snow Timeline from 2003 to 2017

2003	Lake snow was first reported by fisherman.
2008	Tina Bayer who was supervised by Marc Schallenberg, began a PhD on climate change impacts on Lakes Wanaka and Wakatipu. This research was funded by the University of Otago. Marc Schallenberg and Tina Bayer collected unusual samples from Lake Wanaka, and lake snow was identified.
2009	
2010	<i>Southland Times</i> released an article about the Queenstown Lakes District Council (QLDC) concerns with algae clogging up domestic water filters in Wanaka. Marc Schallenberg uploaded a YouTube video on lake snow in Lake Wanaka. Amy Weaver, supervised by Dr Schallenberg at Otago University, begins an ORC-funded PhD (\$50k p.a for 3 years) to study the effects of land-use development on the health of Lake Wanaka. Schallenberg presented data and information on the lake snow issue in Lake Wanaka at the annual New Zealand Sciences Society Conference. Schallenberg notified the ORC of the existence of lake snow in Lake Wanaka. The <i>Otago Daily Times (ODT)</i> released an article on Wanaka residents disgruntled about algae clogging filters.
2011	QLDC funded a report on the lake snow problem. The report was written by MWH Global engineering company and Schallenberg. It reviewed existing data and published the information. No new sampling was funded. Amy Weaver started experiments looking at the production of transparent exopolymeric particles (TEP) involved in the formation of lake snow in Lakes Wanaka, Wakatipu and Hawea.
2012	Schallenberg submitted a research proposal to QLDC to study lake snow in Lake Wanaka (\$46k for 1 year) and this was declined.

	The <i>Southland Times</i> released an article about the cost of the Wanaka water supply upgrade due to lake snow.
2013	Guardians of Lake Wanaka hosted a freshwater pest symposium at Wanaka. Dr Schallenberg presented his research to date on lake snow. Tina Bayer submitted her thesis at the University of Otago.
2014	October 20: Helen Trait (former Chairperson of Guardians of Lake Wanaka) sent letter to Peter Bodeker (Chief Executive of ORC) informing him of the issues, concerns and actions proposed at Guardians of Lake Wanaka meeting.
2015	January: lake snow was confirmed in Lake Coleridge, Canterbury, New Zealand. March: Schallenberg requested co-funding from ORC (e.g., \$10–20k) to go towards a \$4 million research proposal led by University of Waikato on the health and resilience of NZ lakes and estuaries. No co-funding was offered. August: Schallenberg submitted a research proposal to the University of Otago Research Committee (\$90k p.a. for 2 years) and this was declined. Schallenberg's Canadian colleague Émilie Saulnier-Talbot tried to get a National Geographic grant (\$10k) to come work with Dr Schallenberg on lake snow, but this was declined.
2016	February: ODT article "Lake snow threatens Wanaka". March 2: Don Robertson (Chairperson of Guardians of Lake Wanaka) sends a letter to Nick Smith (Minister of Environment) about his concerns surrounding ORC actions on lake snow and provides recommendations. March: Schallenberg submitted a Marsden Fund proposal to work on lake snow (\$350k p.a for 3 years) and this was declined. March 23: ORC committee meeting regarding lake snow May: Lake snow was confirmed in Lake Wakatipu. May–October Lake snow was repeatedly in the media (TV, radio, newspapers and websites). Schallenberg and his colleagues start calling lake snow "lake snot" to better reflect what the algae looks like. June 12: Robertson sent a letter to ODT editor regarding comments by Stephen Woodhead (ORC Chairperson) mentioned in an <i>ODT</i> article. June: Amy Weaver submitted her PhD. One of the chapter looks at TEP fluxes from rivers and TEP formation in the lake water. August: Phil Novis submitted a research proposal to Our Biological Heritage National Science Challenge to work on lake snow (\$225k p.a. for 2 years) and this was declined. August 3: Adam Uytendaal discussed lake snow problem and its environmental drivers at ORC committee meeting. August 21– 26: 24th International Diatom Symposium held in Québec City, Canada. Lake snow research in NZ was presented by Saulnier-Talbot, colleague of Marc Schallenberg. September: ORC funded Dr Phil Novis to carry out genetic analysis of chloroplasts of <i>Lindavia intermedia</i> populations (\$30k). September: ORC started its scheduled decadal state of the 3-year environment monitoring round of the deepwater lakes. Previously stopped sampling in 2009. ORC collected their first lake snow sample. September: lake snow was confirmed in Lake Hawea. September 28: ORC committee meeting discussed research gaps in lake snow. November 23: ORC committee meeting discussed technical workshop on lake snow, location of lake snow, and sampling methods used to collect algae. December: ORC hosted a workshop on lake snow.
2017	March 22: ORC committee meeting summarises lake snow technical workshop that was held in December 2016 and identifies research priorities. June: Novis and Schallenberg submitted a research proposal to study techniques and technologies to accurately monitor and measure lake snow to Smart Ideas research fund of the Ministry of Business, Innovation and Employment (MBIE). June 14: ORC meeting accepted and supported Novis's research proposal and discussed genetic work carried out by Novis, and trophic lake sampling programme. June: National Institute of Water and Atmospheric Research (NIWA) completed report of testing the effectiveness of MPI "Check Clean Dry" programme to control lake snow. This was commissioned by the ORC. June: <i>Lindavia Intermedia</i> (lake snow algae) confirmed in many Canterbury high country lakes.

August: Dr Novis's genetic research confirming whether lake snow is invasive or endemic to New Zealand was released to the ORC. ORC is evaluating the report before the results are released to the public.

September: Novis's research confirmed that lake snow is an introduced pest from United States of America.

The timeline was constructed to ensure that important frames, perceptions and connecting events from 2003 to 2017 could be analysed and compared to one another, to allow a sense of similarity and differences over time to be highlighted and understood. Semi Structured Interviews were also used during the data collection process to gain greater depth and insight into frames and perceptions of professional actors through the biosecurity management planning process.

4.3.2 Semi Structured Interviews

Primary data were gathered from a total of 4 semi-structured interviews. Semi-structured interviews were considered a way to initiate less formal discussions allowing the interviewee to elaborate on issues they considered important. Interview questions were developed based on literature and theory underpinning this research. Semi structured interviews were carried out across a range of professional actors involved in the management of lake snow. Initial phone calls and emails were made and sent to a range of potential professional actors explaining the research project and request an interview. On a verbal or written agreement an interview time and date were set up. Once interviews commenced, use of the snowball technique enabled the identification of potential interviewees. Participants interviewed are listed in Table 4.1.

Table 4-2: List of Interviews

Interviewee	Occupation
Dr Marc Schallenberg	Freshwater Scientist from University of Otago.
Dr Phil Novis	Phycologist Researcher at Landcare Research.
Dr Adam Uytendaal	Water quality scientist at Otago Regional Council.
Dr Don Robertson	Chairperson of Guardians of Lake Wanaka, Member of Guardians of Lake Hawea.

Interviewees were interviewed at places and times of their preferences, ranged from face to face or phone interviews. The interviews were between 30 and 60 minutes in duration, notes were handwritten. Later on, notes were typed up and sent to the interviewees to ensure that they were happy with what had been written and this also provided an opportunity for the interviewee to elaborate on key points. Several attempts were made to contact other professional actors, suggested by interviewees, however no response was received. Interviewees that participated had vested

interested and provided invaluable input to this research. Appendix B contains a sample of the original interview questions.

4.4 Limitations

The case study analysis of one regional council's approach to lake snow is not a representative of every regional council's response to biosecurity issues in New Zealand. To get a better understanding of regional council's approach to biosecurity it would have been worthwhile to compare two regional council approaches. However, taking into consideration the limitations of time to carry out desk top study and interviews and lack of available data due to the recent discovery of lake snow, it would not have been practical to do a multiple case study. Therefore, this research focussed on a single case study of Otago Regional Council's response to lake snow. A single case study allowed a comprehensive study of lake management to be undertaken. A multiple case study on regional council's approach to biosecurity issues in New Zealand does present the opportunity for future research to be undertaken. Further research into professional, community and recreational sections could provide a greater insight into concerns, understanding of invasive species and management planning processes.

4.5 Summary

In summary, the combination of methods (e.g. triangulation, document analysis and semi-structured interviews with professional actors involved in lake snow management and control) provided sufficient information to establish insights relevant to research aims and objectives.

Chapter 5

Results and Analysis

5.1 Introduction

The approach to lake snow has been strongly influenced by different frames created by key players. Analysing the framing and frames of lake snow contributes to understanding how Otago Regional Council responds to invasive pests in Otago, New Zealand. In this section the management process that key actors have taken to identify lake snow as an invasive species will be explained. This section expands on key point identified in in Table 4-1.

5.2 Finding Lake Snow

Sometime during 2003, some unknown algae was found in Lake Wanaka by a fisherman. He reported a fouling of fishing lines. He found an unfamiliar slime sticking to fishing line and reel. Five years later, Dr Marc Schallenberg, a University of Otago freshwater scientist was collecting water samples with PhD student Tina Bayer in Lake Wanaka when they came across the algae that was later identified by Schallenberg as lake snow. At the time, Schallenberg thought this substance could be common algae that occurs in international lakes and oceans. In years to come, *Cyclotella Bodancia* (*Lindavia intermedia*) would be recognised as a diatom, a group of algae, that produces mucus. It was initially referred to as lake snow but would eventually become known as lake snot. Since he found lake snow in Lake Wanaka, Schallenberg has become involved in researching the establishment of lake snow in Lake Wanaka and has sought to encourage and develop research to understand lake snow in New Zealand. He has supervised numerous students on this research and has completed or attempted to study lake snow with his research colleague Dr Phil Novis, a freshwater scientist working with Landcare Research. These scientists saw lake snow as a potential threat to New Zealand lakes.

5.3 Lake Snow Established in Lake Wanaka

By 2010, Schallenberg had become vocal in the media, raising concerns about lake snow and he interacted with government and NGOs to gain insight into the introduction of lake snow into New Zealand. In 2010, Schallenberg released an informative YouTube video on the discovery, formation, and causation of lake snow and its effects on the residents and the ecological composition of Lake Wanaka (Schallenberg, 2010). He explained that lake snow is formed when the “dominant algae *Cyclotella* secretes polysaccharides that cause organic materials to bind together, to resemble a snowflake”. Schallenberg maintained that lake snow was stimulated by climate change and nutrients. He explained that lake snow was a concern because it was a “fouling fishing lines, clogging up

reticulation systems, washing machines and showers, creating a nuisance for the community”. Furthermore, in 2010, the *Southland Times* provided key excerpts from an interview conducted with Schallenberg. During this interview Schallenberg restated what he discussed in his YouTube video about the discovery of lake snow, and suggested that lake snow needed to be researched thoroughly in order for conclusions to be drawn about the risk it posed, to confirm the origins of lake snow and to explain why lake snow was in Lake Wanaka (Johnston, 2010). The video and article portray lake snow as a potential threat that people need to be aware of, and shows the effect it can have on people and the environment. The framing is based on Schallenberg’s knowledge of international research and data on lake snow and marine snow. Figure 5-1 shows a photo of Dr Marc Schallenberg from the Youtubee video and Figure 5-2 shows a sample of lake snow taken from Lake Wanaka in 2010.



Figure 5-1: Photo of Marc Schallenberg (Source: Schallenberg, 2010)

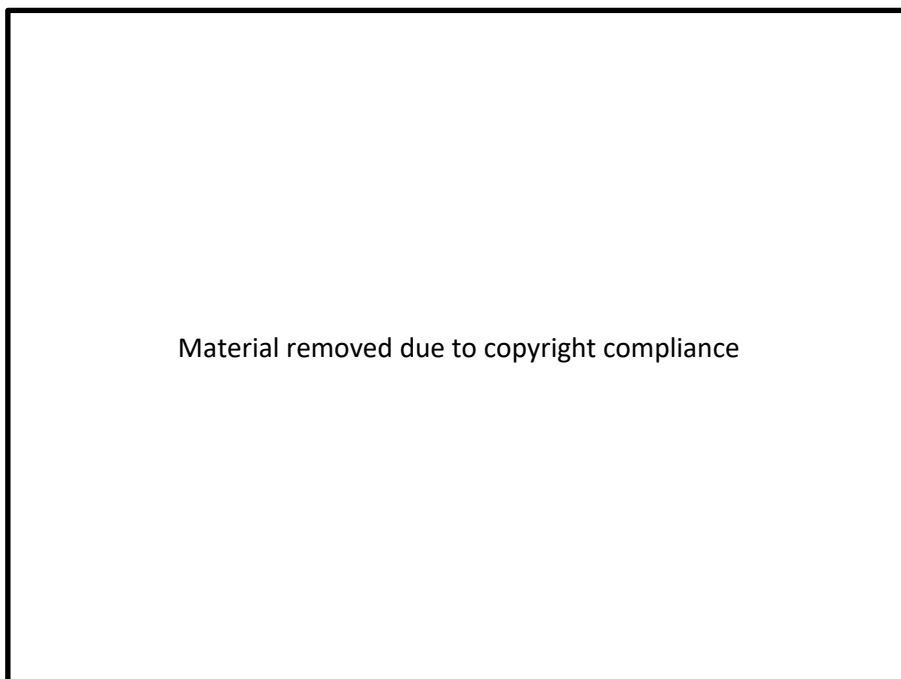


Figure 5-2: Sample of lake snow taken from Lake Wanaka by Marc Schallenberg (Source: Schallenberg, 2010)

In 2010, Schallenberg directly notified ORC of the existence of lake snow. ORC considered Schallenberg's concerns surrounding the formation of lake snow; however, due to the lack of supporting data on whether lake snow would spread to other Otago lakes, the ORC formed their own perception of lake snow. Dr Adam Uytendaal, an ORC freshwater scientist who became actively involved in researching and monitoring lake snow in alpine lakes, confirmed that when ORC first became aware of lake snow in 2010, it was perceived as "no point of concern", and was "not on council's radar" and therefore no requests were made to follow up on lake snow (Uytendaal, personal communication, 2016). In the beginning, ORC framed lake snow as not a problem because of the uncertainties surrounding whether lake snow would become an issue for the Lake Wanaka community.

However, the Guardians of Lake Wanaka had a different perception of lake snow. The Guardians of Lake Wanaka were established under the Lake Wanaka Preservation Act 1973. The purpose of this Act is to prevent the water body of the lake from being impounded or controlled, to preserve the water levels and its shoreline and to maintain and improve the water quality. Under the Act, the Guardians of Lake Wanaka are required to report and make recommendations to the Minister of Conservation on any matter concerned with the quality of Lake Wanaka. The Guardians were deeply concerned with ORC's lack of concern or interest in lake snow and how lake snow was affecting the water quality and the community (Dr Don Robertson Chairperson of Guardians of Lake Wanaka, personal communication, 2017). From the very beginning, the Guardians have framed lake snow as an issue because of the current and potential impacts it may have on the lake and community in the future. The Guardians strongly believe it is important to be proactive to ensure that lake snow does not become an irreversible problem for the community and environment. The lack of response from the ORC towards lake snow influenced the Guardians of Lake Wanaka to play an active role in corresponding and advising ORC to act, interacting with the community through community meetings, and correspondence and the organisation of seminars. For example, in 2013 the Guardians hosted a seminar titled "Lake Wanaka—for better or worse? Planning for the future." At this seminar Schallenberg presented information as an individual and that which he had co-researched with his colleague Phil Novis of Landcare Research and postgraduate students. Schallenberg presented information on the pressures causing Lake Wanaka to change, why it might harbour lake snow and what it might mean for the future of Lake Wanaka. Schallenberg presented a diagram (Figure 5-3) to illustrate the interaction between pressures and responses on Lake Wanaka.

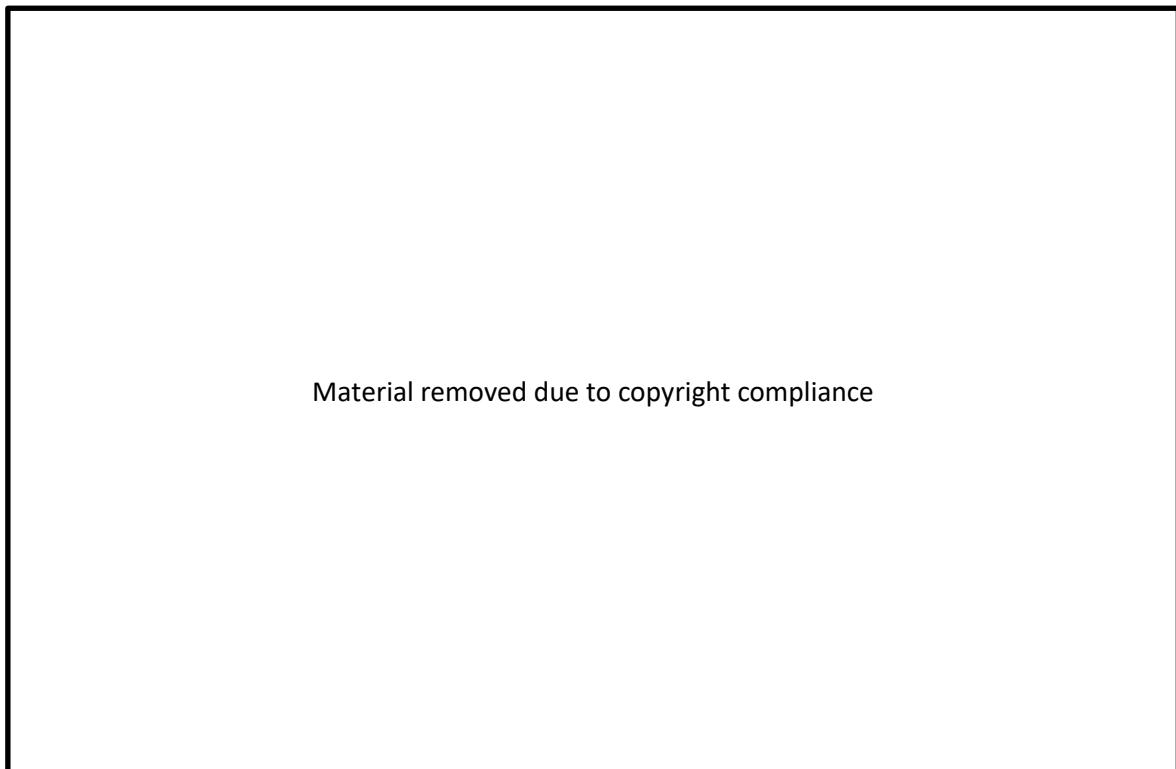


Figure 5-3: Pressure and responses diagram of Lake Wanaka (from Guardians of Lake Wanaka, 2013, p.5.).

Figure 5-3 demonstrates the pressures facing Lake Wanaka that include land use change (tenure review, land development and intensification of farming), increased presence and treatment of non-native species (water fleas and *Lagarosiphon*) and climate change (warmer temperature, increasing water supply and usage, more wind). Schallenberg claimed that the pressures have influenced a composition shift in dominant algae in Lake Wanaka. The dominant algae in 1994 and 2002, known as *Picyanobacteria* (i.e., due to the microscopic size of the algae) shifted to dominance by a *Cyclotella* diatom (a larger organism) that was commonly found in Lake Wanaka in 2008. Schallenberg stated that these changes are likely to have a “direct influence on the lake and catchment composition” (Guardians of Lake Wanaka, 2013). Here Schallenberg was framing lake snow and its establishment in Lake Wanaka as an indicator of the overall health of the lake, suggesting that the lake is in decline and could potentially lead to worse problems in the future.

5.4 The Spread of Lake Snow

In 2016, lake snow was confirmed to have been found not only in Lake Wanaka but also Lake Wakatipu, and Lake Hawea. It was at this point many organisations began changing their perception and approach towards lake snow. The spread of lake snow was reported repeatedly in the media, Table 5-4 below demonstrates the media articles released in 2016.

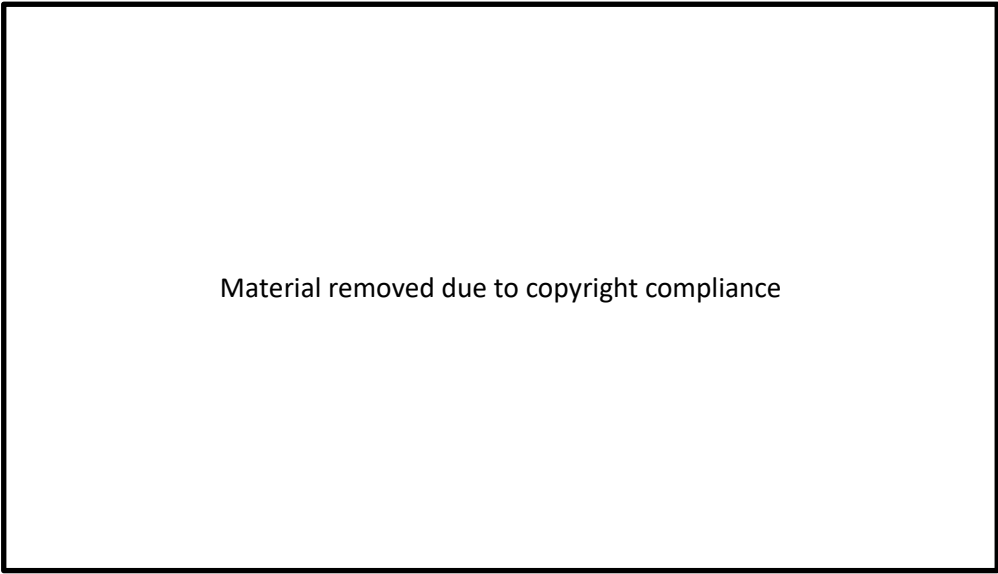
Figure 5-4 Media articles on lake snow released in 2016

Date	Description
March 12, 2016	Journalist McKenzie-McLean released an article illustrating scientists' concern over lake snot becoming a national problem in New Zealand (McKenzie-McLean, 2016).
March 12, 2016	Journalist Mitchell published a media articles about a "rare 'Lake Snot' mysteriously spreading through South Island lakes." (<i>Stuff</i> , 2016).
September 12, 2016	<i>Radio New Zealand</i> discussed lake snow in comparisons to didymo, referred to as the "the new didymo".
October 8, 2016	Journalist Cook released an article on <i>Stuff</i> about the possible connection between the algae and the flea leading to an increase in lake snow bloom in Lake Wanaka. (Cook, 2016).
2016	A media release on "lake snot" spreading among iconic South Island lakes was released by a freshwater scientist on <i>Scoop Media Ltd</i> (Schallenberg, 2016).

The spreading of lake snow presented problems for residents, such as clogging up domestic water filters. The spread of lake snow and its appearance on fishing lines and domestic water filters led to the vernacular term "lake snot" coined by Schallenberg and Novis. This was because of its similarity to didymo, an invasive diatom in New Zealand rivers that is sometimes known as "rock snot" (Novis, Mitchell, & Podolyan, 2017). That the diatom had spread from where it was thought to have first originated, Lake Wanaka, changed how scientists started describing it—from snow to snot.

The Southland Times released articles revealing the spread of lake snot to other South Island lakes. Schallenberg was interviewed and expressed his concerns surrounding the establishment and uncertainty about lake snow in Lakes Wanaka, Wakatipu and Hawea.

Schallenberg noted that "much remains unknown about lake snot, including what conditions cause it to appear, how to get rid of it and whether it has long-term ecosystem impacts. It is unusual in that it primarily affects clean lakes" (Mitchell, 2017). Schallenberg is framing lake snow as a research endeavour, and has a vested interest in understanding and researching the conditions that have led to lake snow bloom in the pristine, deep lakes of Otago. *The Southland Times* article was published six years after the first statement in 2010 when Schallenberg first raised the issue. In 2017, he was explaining that there had been limited progress towards researching lake snow and that the lack of progress has been influenced by lack of funding, and highlighted "we have had little success attracting research funding from any level of government to study and answer questions on lake snot" (*The Southland Times*, 2016, p. 12). Schallenberg was articulating his concern and frustration surrounding the lack of progress that had been made towards finding answers about the production of lake snow, due the lack of funding provided by ORC, MBIE, and other organisations. Examples of Schallenberg's proposals and application declines are shown in Table 4-3.



Material removed due to copyright compliance

Figure 5-5: Lake snow/snot attached to a Wanaka water filter (source: Cook, 2016).

In response to Schallenberg's call for action in 2016, Otago Regional Council has been looking for environmental drivers that have influenced lake snow to bloom and spread to other lakes. Cook, a newspaper journalist, published an article on in September 2016 on biosecurity concerns and the possible connections between the introduced North American water flea (*daphnia pulex*) and lake snow in Lake Wanaka. In the article, a number of key players were interviewed, including Dr Palmer (Director of engineering, hazards, and science at Otago Regional Council), Dr Olsen (Resource manager for Otago Regional Council) and Dr Robertson (Chairperson of Guardians of Lake Wanaka). In the article, Palmer stated that "the possibility that *Cyclotella Bodancia* [lake snow] is an invasive species poses significant biosecurity implications to Otago and elsewhere across New Zealand" (Cook, September 8, 2016). Dr Palmer's statement relates to the suspected link between "lake snot" and an introduced North American water flea. Uytendaal, ORC freshwater scientist, confirmed at a council meeting in 2016 that there was a possible connection. Uytendaal believes that environmental drivers that are influencing the change include climate change, water fleas grazing on phytoplankton, and possibly increased nutrient loading in the lakes. However, in September 2016 Uytendaal advised that there are still gaps in understanding why lake snot was occurring. Therefore, he suggested that further research is required, for example, a DNA analysis comparing lake snow with overseas strains, and lake sediment core analysis to establish the colonisation history of *Cyclotella* and the environmental influences of lake snow in New Zealand (ORC, 2016). Hence, at this time, the ORC was continuing to frame lake snow as an unknown entity that requires more research to determine whether it is a biosecurity threat in Otago alpine lakes.

This uncertainty surrounding lake snow led ORC to organise a technical workshop to discuss current knowledge and sampling methods. The technical committee meeting held on 23 November 2016

confirmed that the technical expert workshop would be held in the third week of December 2016. The primary objectives of the workshop were:

- 1) to develop and prioritise research questions relevant to the identification of potentially feasible methods of managing the effects of lake snow; and
- 2) to scope the methodology, timeframe and resource requirements for answering each research question.

The technical workshop would ensure that research would be focused around solutions for lake snow and would lead to the next steps that need to be taken. In promoting the workshop, Otago Regional Council stated that they could become “world leaders in analysing lake snow” (ORC, 2016). Many different organisations were invited to present at the workshop held in December 2016 including Landcare Research, Cawthron Institute, NIWA, University of Waikato, University of Otago, MPI, Queenstown Lakes District Council, Environment Canterbury, Environment Southland and ORC. At the workshop, ORC representatives Uytendaal and Olsen described how ORC’s past State of Environment (SOE) lake sampling programme had a limited ability to detect unknown organisms such as *Lindavia intermedia* (lake snow) in Otago Alpine lakes, and consequently a more targeted monitoring programme was required (Ryder, 2017). Nevertheless, ORC’s state of the environment monitoring programme, a three-year-long intensive boat-based monthly monitoring programme began in September 2016 on Lakes Wanaka, Hawea, Wakatipu and Hayes (Ryder, 2017). The monitoring programme includes sampling zooplankton, phytoplankton and other parameters and using a “snow tow” to detect the presence of lake snow. A snow tow is a downrigger towed through the water by a boat at a set depth, speed and distance, allowing a quantitative assessment of lake snow (Ryder, 2017). The terms lake snow and lake snot are used interchangeably by ORC. Overall, the workshop participants agreed that to manage the effects of lake snow, further research was essential to understanding and managing it.

Dr Don Robertson (Chairperson of Guardians of Lake Wanaka) was disappointed with the ORC response to lake snow. During an interview on Radio New Zealand, Dr Robertson claimed that he has “seen no change or acknowledgement in addressing and managing lake snow until now. Actions towards lake snow should have occurred 10 years ago.” (RNZ, 2016). Robertson believes that a “comprehensive management plan that includes the community’s values and outcomes and a monitoring plan for the next few years should be formulated sooner rather than later.” He states that “the plans will be beneficial and will give the community a better idea of where the ORC is heading” (Robertson, personal communication, 2017). At the beginning of the year 2016, Robertson sent a letter to Minister for the Environment Dr Nick Smith regarding his concern surrounding ORC’s ability to adequately manage

Otago's deep-water lakes due to ORC budget constraints, and continual rejection of the Guardians' offer to work with the council.

The Guardian advised the Minister for the Environment to assign Ministry for Primary Industries (MPI) staff and funding to support a lake snow research project (for full letter refer to Appendix B.1.). Robertson was then framing lake snow as an issue that was getting worse and needing urgent attention, which is why he sent a letter to the Minister. Providing advice to the Minister is part of the Guardians' responsibility under the Lake Wanaka Preservation Act 1973. The Minister's response to Robertson's letter was not revealed in this analysis. However, in the lake snow technical workshop organised by ORC in December 2016, ORC explained that the MPI's involvement in lake snow would require the algae to be identified as a new organism to New Zealand. Once a new incursion had been validated, the process would move to a response team. Then MPI could assist regional councils with diagnostics and logistics (Ryder, 2017). Without designation as a biosecurity threat, which would invoke central government assistance, responsibility for lake snow rests solely with the local regional and district councils.

In response to Robertson's concerns that the ORC response to lake snow was inadequate for managing the algae, Olsen, ORC manager of resource science, "agrees that ORC has been slow to act, but lake snow now has the council's attention" (RNZ, 2016). Currently, ORC staff are working with laboratories and services providers to develop techniques to improve monitoring (Ryder, 2017)., ORC continued to hesitate and await the release of research results before a decision surrounding management could be made. Hence, the ORC had shifted its framing of lake snow from no risk to biosecurity risk; therefore it became a research priority in 2016.

5.5 2017 – Discovery of an Invasive Pest Research Priority

The impact of lake snow on the lake and community and the lack of knowledge surrounding the organism's occurrence and spread has spurred ORC to researching lake snow. In 2017 ORC was continuing to increase its efforts to research and manage lake snow. ORC held a technical committee meeting on the 22 March. ORC discussed the technical expert workshop that was convened in December 2016, and identified that lake snow is a research priority for ORC. The priority research areas were discussed and identified in the council committee meeting and have been summarised in Table 5-1.

Table 5-1 Otago Regional Council Priority Research question (Modified source: ORC, 2017a).

Research Questions	Priority Level	Funding Allocated	Common Status
Is <i>Lindavia intermedia</i> a native or non-native species?	High to Immediate Priority	\$30, 000 contract was signed with Phil Novis (Landcare) in 2016.	Completed in August 2017.
What are the environmental drivers that have influenced the production of lake snow?			
How to slow down the growth of lake snow?		ORC commissioned MPI to work with NIWA to determine whether the MPI Check, Clean, Dry programme is effective.	Completed in June 2017.
Developing technologies for effective sampling and monitoring of lake snow.	High to Medium Term		Investigated by ORC.
Supporting citizen science.		\$10,000 has been allocated.	Unknown.
Historical <i>L. intermedia</i> dynamic correlated to environmental drivers in our lakes.	Medium term:	\$219,000 has been allocated for a 3-year delivery to support the postgraduate research.	Unknown.
What is the relationship between didymo and <i>L. intermedia</i> ?		\$19,000 was allocated.	Unknown.

Control the establishment of lake snow

ORC contacted MPI to engage with NIWA to review the effectiveness of the Check, Clean, Dry programme on *Lindavia Intermedia* (Ryder, 2016). The report was completed in June 2017 by Kilroy, and Robinson (Ryder, 2016). The report identified that:

- 1 minute with dishwashing liquid gave greater than 90% effectiveness;
- 1 minute with bleach gave a greater than 99% effectiveness;
- hot water provided an ambiguous result that needed to be further tested;
- freezing was 100% effective;
- drying at room temperature until dry to touch was greater than 99% effective; and
- salt was not recommended without further testing.

Based on the results provided by NIWA, ORC has identified an opportunity to investigate other readily available products that could be a more effective treatment method, particularly for boat users. MPI advised regional councils to continue to promote Check, Clean, and Dry between waterways as a recommended treatment options for lake snow.

Develop sampling technologies

Monitoring is one of the ORC's key responsibilities under the Resource Management Act 1991, to ensure unusual phenomena can be detected and mitigated to protect the lake. Otago Regional Council has received criticism from former New Zealand academic and freshwater scientist Professor David Hamilton and community member's for not funding scientific monitoring for the lake (Waterworth, 2017b). Kerrie Waterworth, *Otago Daily Time (ODT)* Journalist, asked Ella Lawton (passionate community member, and scientist [social and natural]) and Gary Kelliher (former ORC councillor who runs agriculture, roading and an office accounting systems business in Alexandra) for their views relating to ORC control on biosecurity matters such as lake snow (Waterworth, 2017e):

It is the ORC's role to regulate the impact of pests and hold the landowner accountable if pests cause an issue. ORC and Land Information New Zealand need to proactively work with stakeholders to ensure that there is no further spread of *Lagarosiphon* and that our lakes and rivers can be enjoyed by the community. It is very likely that lake snow is a result of changing water quality. One of the ORC's core purposes is to manage impacts on water quality. They cannot manage what they do not understand; they need a science programme, funding, and an action plan for alpine lakes research.

Ella Lawton (Waterworth, 2017e).

ORC is being too conservative in its approach to both *Lagarosiphon* and lake snow. There is very clear community concern towards these weeds and the ORC needs to play a much stronger role in supporting the science to understand them and funding towards removing or eradicating them. Also, I think the problem needs to be considered for all lakes and their connecting rivers not just chasing the source in Lake Wanaka. The Clutha

and Kawarau rivers as connectors and Lake Dunstan have varying levels of effort required.

The sooner this is undertaken, the lesser the task.

Gary Kelliher (Waterworth, 2017e).

The articles on Ella Lawton and Gary Kelliher views on ORC approach to lake snow reveal that they both believe that ORC is not doing enough to manage and control lake snow. ORC need to play a stronger role to managing the impacts on not just Lake Wanaka but all the lakes in Otago, New Zealand. This will contribute to ensuring that that other lakes being protected from further biosecurity threats.

Monitoring buoys have been suggested by freshwater scientist as a solution to monitoring but Uytendaal (personal communication, 2017) states that is “not viable to maintain monitoring buoys in every lake in Otago as this expensive and resources are limited”. Monitoring buoys from historical experience may not be able to display accurate results due to the depth of Lake Wanaka (300m) and Lake Wakatipu (400m) (Waterworth, 2017c). Kerrie Waterworth *Otago Daily Times* Journalist wrote an article about monitoring of the lakes and Dr Stephan Woodhead was one the people that were interviewed. Dr Stephan Woodhead stated that it is not “ORC’s role to commit regional rate payer’s money for Otago University scientific focused monitoring inquisitions” (Waterworth, 2017c). Stephan Woodhead identified lake snow research is beginning to affect other regions in New Zealand such as Canterbury, therefore it is not their responsible to fund research projects when lake snow is or may be a national issue. The MPI will not act until lake snow has been confirmed as an introduced pest.

However, Robertson wrote a letter to the *Otago Daily Times* concerning Woodhead’s comments. The letter revealed that Robertson found Woodhead’s comments “baffling and worrying.” Robertson believes that if Woodhead sees lake-management research as inquisitions, and the role of ORC as excluding university-based analysis then what hope is there for management of Lake Wanaka, Lake Wakatipu and Hawea catchments. For the full letter refer to Appendix B.2. Robertson was not pleased with Woodhead’s response, and community members Lawton, Kelliher and Robertson believe that, regardless of MPI’s lack of support, it is still ORC’s responsibility to fund research. ORC had admitted in the earlier stages of identification and discovery of lake snow that more research was required for management approaches to be developed and implemented, and then continued to refuse to fund university projects. The ORC frames and claims on lake snow management is contradictory and has caused conflict to arise between organisations. However, ORC continued to stand by their decision to review the monitoring technologies such as a monitoring buoy in Lake Manapouri and other technologies, before the ORC invested in monitoring equipment (Waterworth, 2017c). ORC wished to ensure that adequate viable solutions are researched thoroughly to ensure money is not wasted and effective monitoring can be achieved.

Genetic report – invasive species

In September 2016, ORC signed a \$30,000 contract with Novis to carry out genetic analysis of chloroplasts of *Lindavia intermedia* populations. The study was commissioned to determine whether lake snow is an invasive species in New Zealand.

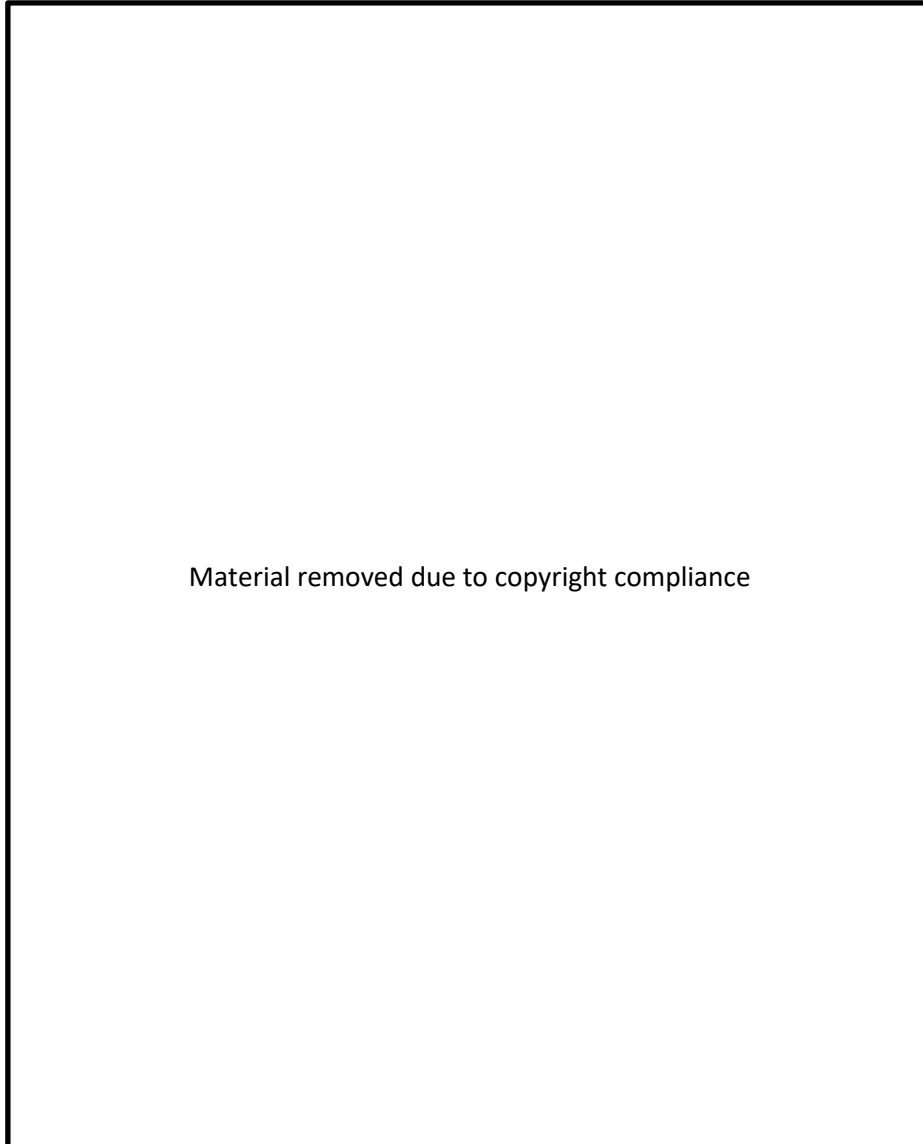


Figure 5-6 Results revealed from the genetic analysis on New Zealand and international lake snow samples A. Lake Coleridge, B. Lake Wānaka. C. Lake Wakatipu. D. Lake Youngs (WA, USA). E. Cultus Lake (Canada). F. Lac Léman (Switzerland). All shown at the same scale (the bar in E. is 10 μ m).(source: Novis, Mitchell, & Podolyan, 2017).

The genetic report was released to ORC in August 2017 for evaluation (Waterworth, 2017d). The genetic report results were released in the *Otago Daily Times* on 14 September 2017 by journalist Tim Miller. The article confirmed that lake snow is highly likely to have been introduced into New Zealand from Lake Youngs, near Seattle, Washington. ORC revealed that “no immediate measures would be taken to stop the potential spread of lake snow”; however, a more “intensive research programme” would get under way to understand the organism and work towards solutions to minimise the effects

of lake snow. Environment Canterbury, Environment Southland and the MPI would be involved in the research process (Miller, 2017). Robertson (Chairman Guardians Lake Wanaka) stated that it was a “positive step to understanding lake snow and agreed that more research was needed”, and advised that a “comprehensive management and monitoring programme” was still needed. Overall, Robertson was pleased with the ORC response to lake snow.

Another article was released by Waterworth, following on from the first article, which revealed that MBIE had announced a million-dollar three-year endeavour fund grant to Landcare Research to determine the causes of lake snow production. (Waterworth, 2017f; Novis, Mitchell, & Podolyan, 2017). Schallenberg will also be involved in aspects of the lake snow Landcare Research project. Schallenberg was not surprised that lake snow (*Lindavia intermedia*) came from overseas, because it had not been reported until the early 2000s. However, Schallenberg said that although lake snow cannot be eradicated from Otago alpine lakes, it can provide lessons to be learnt to prevent future invasive species from being introduced into New Zealand (Waterworth, 2017f).

5.6 Summary

This section draws together the frames of key players involved in grappling with lake snow and how these frames have influenced Otago Regional Council's approach to addressing lake snow, this is summarised in Table 5-2. Table 5-2 provides a summary of the perceptions and approaches from 2003 to 2017.

Table 5-2 Summary of perceptions and approaches taken towards lake snow 2003-2017

	2003-2008	2009-2014	2015-2016	2017
Scientists	Schallenberg interested in lake snow and began research.	Frustrated by lack of interest and lack of research funding for lake snow.	Funding made available to Phil Novis to study genetics of lake snow.	Genetic study has been completed.
Framing	Potential threat	Biosecurity risk	Biosecurity risk	Invasive species
ORC	No knowledge of lake snow.	No concern over lake snow.	As lake snow spreads to other lakes, research into lake snow began with monitoring programme, technical workshops. Pressure from the media, scientists and Guardians to take action.	Concerned about lack of support from government. lake snow production is a high research priority.
Framing	Unknown entity	A local issue	A potential threat	Invasive species
Guardians of Lake Wanaka		Guardians were concerned and began gathering information from scientists.	Concerned and frustrated, and disappointed by ORC's slow response and inadequate management plans. ORC not willing to work with Guardians. Guardians formed Lake Wanaka Trust.	Happy that progress was occurring but believed that it was ORC's statutory responsibility to protect lake and they could be better by producing a comprehensive management plan.
Framing	Unknown entity becoming a nuisance for the community	Biosecurity threat	Biosecurity threat	Invasive species
MPI	No knowledge.	No concern.	No scientific confirmation of lake snow being invasive or endemic.	Unknown until results are released.
Framing	Unknown entity.	A local Issue.	A local issue.	Potential national issue.

The freshwater scientists framed lake snow as a potential introduced biosecurity threat, and their frame was constructed through knowledge drawn from international research and data, and current research. **Guardians of Lake Wanaka** representatives of the community framed lake snow as a biosecurity threat and nuisance from 2010 to 2017. Their frame was constructed by the local impacts the diatom was having on the community, recreationists, and aesthetic values of the lake.

In comparison, **Otago Regional Council** are government statutory bodies under RMA are responsible for managing lake quality and quantity. ORC framed lake snow in the beginning as not a problem; this framing was influenced by inadequate research and limited ability to manage lake snow. The amount of research that could be carried out by scientists was restricted due to the lack of available funding. ORC's capacity to manage lake snow was limited due to lack of available technology to adequately monitor invasive pests in Lake Wanaka. However, in 2016, ORC's perception of lake snow changed when lake snow began to spread to other waterways such as Lakes Wakatipu and Hawea. ORC began to experience pressure, and recognised how other key organisations such as MPI, Guardians, community, scientists and the media were framing lake snow as a biosecurity threat to lake composition and community recreation. ORC started to frame lake snow as a biosecurity risk and, thus, a research priority. Identifying the origins was a key aim of the council. In 2017, lake snow was identified as an invasive species, encouraging ORC to frame lake snow as an issue, but without clear direction on the management of lake snow. Lastly, originally framed lake snow as a local issue, that is, an ORC responsibility. The MPI frame was constructed by research, and there was no existing research suggesting that lake snow was introduced into New Zealand. However, currently MPI may frame lake snow as a national invasive pest due to the release of the recent genetic analysis which suggested that lake snow is highly likely to be an invasive pest.

How each organisation frames and approaches lake snow is influenced by the others and constructed strongly by available knowledge, research, funding, environmental drivers, available technology, institutional arrangements and regional council capacities. Overall, there was no solution formulated for didymo and the same may apply to lake snow, because it is impossible to eradicate and difficult to manage, regardless of the amount of funding provided and research that is carried out. This has been recognised by Schallenberg, who stated that it was too late to do anything with lake snow because it had spread to many lakes. Without certain information and technologies, invasive pests cannot be adequately managed or monitored. Schallenberg advised that invasive species identification technologies and monitoring should be improved in the future to ensure that unwanted pests can be identified in the earlier stages of establishment. How lake snow has been framed and approached raises many issues for planning and how the biosecurity framework operates; this will be explored and discussed in greater detail in the next Chapter to Identifying potential 'implementation gaps' that influence the overall effectiveness of the biosecurity framework within the New Zealand context.

Chapter 6

Discussion

The primary aim of this research was to identify potential ‘implementation gaps’ that influence the overall effectiveness of the biosecurity framework within the New Zealand context. Otago Regional Council’s approach to lake snow (algae) will be used as case study. Hence this chapter aims to achieve this objective by expanding on the frames and framing literature identified in Chapter 5 and collate these issues into a coherent conclusion. The discussion will also draw from literature on the biosecurity framework, and on risk and uncertainty identified in Chapters 2 and 3. This will allow the biosecurity framework to be evaluated in terms of its strengths and challenges to provide valuable insights into the management of invasive pests in Otago, New Zealand.

In order to achieve the primary aim of this research as outlined above, this chapter will:

- 1) review the shift in frames and framing of lake snow;
- 2) review the institutional arrangements and challenges;
- 3) discuss risk and uncertainty of researching invasive species; and
- 4) Identify ‘Implementation gaps’ that influence the effectiveness of the biosecurity framework with the New Zealand context.

6.1 Reviewing the Shift in Frames and Framing of Lake Snow

From the analysis, it was observed that there was a change in frames and the framing of lake snow from when it was first discovered and began to spread to other waterways until the discovery of lake snow as an invasive species. As a result, this has influenced Otago Regional Councils’ response towards lake snow.

When lake snow was first noticeable in Lake Wanaka, there were a number of key actors, such as freshwater scientists and Guardians, who framed lake snow as a potential issue. Schallenberg and Canadian colleague Saulnier-Talbot recognised the similarity between lake snow in New Zealand and lake snow and marine snow in other countries (International Society for Diatom Research, 2016). Schallenberg had observed the effects that lake snow can have on international lakes and oceans and feared the impact it might have on New Zealand alpine lakes. Similarly, Robertson (Chairman of the Guardians of Lake Wanaka) is from the Wanaka region and had first-hand experience of the effects of

lake snow on the environment; he feared it getting worse and permanently affecting community enjoyment of the beloved lake in the summer months.

However, other key actors, such as ORC were not convinced that lake snow was an issue until hard evidence was displayed by the scientists involved (Schallenberg, and Novis, of Landcare Research). Even when lake snow began to spread, and scientists demonstrated that lake snow would have negative impacts on the composition of Lake Wanaka, and neighbouring Lakes Hawea and Wakatipu, ORC was slow to change its framing and response towards lake snow. The framing and defining of an issue requires building an understanding of the problem: a problem cannot be fully defined if there is limited knowledge and understanding surrounding the topic (Bardwell, 1991). The ORC's slow response to lake snow may have been as a result of limited knowledge and understanding of the lake snow issue, which was exacerbated by the costs of obtaining information through research and the geographical challenges of doing so, given the size of the lake.

Bardwell (1991) argues that organisations rely on familiarity in problem solving and problem definition. Organisations such as a council will solve a problem by reflecting back on past experiences or similar situations. ORC's framing and response to lake snow may have been directly influenced by the recognition of the similarities and differences between lake snow and didymo. Didymo was introduced in the Waiau River, Southland, in 2004 (NIWA, 2014), whereas lake snow was introduced into Lake Wanaka a year early. Both lake snow and didymo became established in pristine freshwater waterways and became a nuisance for waterway users, interfering with angling, sporting and recreational activities, and blocking water intakes. On the discovery of both species, there was very little information on distribution, ecology and their effects on ecosystems, and how to stop the spread and eradicate the pests (NIWA, 2014). They differ in some respects: didymo was a rapid-onset disaster, because it spread rapidly through freshwater rivers in a short period of time, having now spread to 150 South Island waterways (Flynn, 2016). Conversely, lake snow remained dormant in Lake Wanaka until 2016: it is a slow-onset disaster because the organism gradually became established in Otago's alpine lakes over a significant period of time.

The difference in establishment rates may have been linked to the type of preferred freshwater waterways. Didymo thrived in rivers, and because rivers are constantly moving, this may have caused it to spread rapidly through South Island rivers, whereas lakes are static. ORC may have assumed that lake snow was confined and unlikely to spread as rapidly as didymo. How a biosecurity threat is approached is strongly influenced by the rate of establishment.

When didymo was established, MPI and regionals councils quickly reacted and put funding in place to set up research development, and programmes such as the MPI Check Clean Dry programme to stop didymo from spreading to other waterways in New Zealand (Ryder, 2017). Conversely, for lake snow,

ORC did not put monitoring, management or funding in place until lake snow began spreading and became an issue in 2016. The contrast between didymo and lake snow is crucial because it demonstrates the distinctions in how the two organisms were framed by ORC, and this has influenced the different responses and approaches towards managing the organisms.

ORC quickly realised, however, that didymo cannot be eradicated from South Island rivers. When lake snow began to spread, it is possible that ORC recognised that lake snow might not be controllable, similar to didymo. ORC refused to use rate payers' money to fund university postgraduate research on lake snow and strongly believed that if lake snow were a national issue then ORC should not bear sole responsibility for managing the organism (Waterworth, 2017c). ORC's response to lake snow was extremely frustrating for other actors such as freshwater scientists, community and non-governmental organisations who perceived lake snow as a threat that needed to be dealt with quickly before it became unmanageable.

Key actors expressed their concerns to ORC about the spread of lake snow and the pressing need to understand the environmental drivers (climate change, North American water flea and nitrate run-off) that may have influenced lake snow to bloom and spread. Eventually, as it began to spread, ORC began to recognise the severity of lake snow in Otago lakes and began to frame lake snow as a biosecurity risk and therefore, a research priority (Gibb, 2017). Research aims and questions were identified and prioritised and the identification of environmental drivers and origins of lake snow received the highest priority. Once research provided evidence that lake snow was most likely an introduced species from Youngs Lake in Washington, U.S.A, (Novis, Mitchell, & Podoylan, 2017), ORC subsequently began to frame lake snow as an invasive species. How a problem is defined and framed is essential because it guides the strategies and actions to address environmental problems such as biosecurity threats.

This research has shown that understanding how an issue is framed can play an essential role in biosecurity management. Importantly, the research shows that framing takes time and is influenced by a range of factors. Hence there are challenges for planning in a context of uncertainty, which is shown here by the delays encountered in invoking the biosecurity framework by virtue of a range of issues. How an invasive species is framed can highlight and demonstrate how regional councils approach highly uncertain biosecurity threats under the biosecurity framework in New Zealand. There are challenges in framing environmental problems, which has impacted on ORC's ability to respond to lake snow. The challenges that affect the framing of biosecurity threats will be explored in more detail in the next section.

6.2 Review of Institutional Arrangements and Challenges

The institutional arrangements under the BSA strongly influence how biosecurity matters are framed, identified and managed. In this section the institutional arrangements and the challenges raised by key actors will be discussed. Institutional arrangements consist of the central government departments, local government and other non-governmental organisations.

Central Government Organisations

Central government and its departments were responsible for providing direction, guidance and support under the BSA to restrict invasive species from being introduced into New Zealand, and, therefore, they established procedures such as pre-border, and border management, and readiness and response procedures. The main government organisations involved include the Ministry for Primary Industries (MPI), the Department of Conservation (DOC), and research institutes such as the National Institute of Water and Atmospheric Research (NIWA) and Landcare Research.

MPI is the main governing body for managing biological risk through pre-border management and border control. MPI is responsible for providing money, and support, and setting up programmes for regional councils to implement (e.g., the Check, Clean, Dry programme aimed at reducing the spread of invasive pests in New Zealand). MPI could not provide funding until lake snow was confirmed as a “new organism” under the Hazardous Substances and New Organisms Act 1996 (HSNO), and as an invasive pest (Ryder, 2017). Central government expects local councils to limit expenditure in the face of rising demands, caused by lake snow (Drage & Cheyne, 2016).

DOC under the Conservation Act 1987 is responsible for protecting and enhancing natural and historic resources, including biodiversity in New Zealand, through development of biodiversity strategies, conservation programmes and publication of educational and promotional materials (Owen, n.d).

Lastly, Landcare Research, the University of Otago and NIWA are national research institutes that central and local government work with to develop research and gain knowledge to manage invasive pests. Landcare Research was contracted by ORC to conduct research on the genetics of lake snow to determine whether the algae were an invasive species (Ryder, 2017). The University of Otago, through Schallenberg, a freshwater scientist, researched the environmental drivers and pressures influencing lake snow to bloom and the impacts it would have on the composition of Lake Wanaka and the surrounding lakes (Guardians of Lake Wanaka, 2013). In addition, NIWA worked with ORC and MPI to research the effectiveness of the MPI’s Check, Clean, Dry programme on reducing the spread of lake snow through South Island lakes (Kilroy & Robinson, 2017). Research on lake snow has slowly been developed over the last eight years, and especially made headway in 2016 and 2017, however limited amount of money provided by central government and local government for research development

on lake snow has impacted on the local governments ability to understand lake snow in depth. There still remain high uncertainty surrounding environmental drivers and outcomes on ecological composition of Lake Wanaka and how to effectively reduce and manage lake snow in New Zealand.

Local Government

Under the BSA local government in New Zealand is responsible for developing and implementing regional management plans to manage the establishment and distribution of invasive pests in New Zealand. In Otago, the local government (including ORC and Queenstown Lakes District Council [QLDC]) is responsible for managing lake snow. ORC has an important role in working with central government organisations as well as with other councils (Environment Southland, Environment Canterbury) and other non-governmental organisation (Guardians of Lake Wanaka and Hawea) to understand and manage the effects of lake snow on the community and the environment, through seminars, technical workshops and council meetings (Ryder, 2017). QLDC has also undertaken research on improving the domestic freshwater infrastructure to prevent or reduce filters being clogged by lake snow (Ryder, 2017).

The analysis revealed that a number of factors have contributed to how the ORC has framed lake snow. Bardwell (1991) explains that problem framing guides the strategies and actions to address an environmental problem such as a biosecurity threat. Limited budgets for research have contributed to a lack of technology to effectively monitor the introduction and establishment of freshwater pests, a limited understanding of freshwater pests and how to manage them effectively, an overwhelming and growing number of environmental, social and economic issues, and, lastly, a lack of communication and coordination between central, local government and NGOs (Uytendaal, ORC, personal communication, 2017; Don Robertson, Guardians of Lake Wanaka, personal communication, 2017; Ryder, 2017).

Non-Governmental Organisations

Non-governmental organisations work with the councils, or councils delegate powers and functions to non-governmental organisations to contribute to research in biosecurity management under the BSA and conservation protection under the Conservation Act 1987. Non-governmental organisations include community trusts and groups such as Lake Wanaka Trust, Guardians of Lake Wanaka and Guardians of Lake Hawea. Guardians of Lake Wanaka, under the Lake Wanaka Preservation Act 1973, are responsible for preserving and protecting use, development and subdivision of Lake Wanaka. Guardians have played an important role in educating the community and working with ORC to improve the management of Lake Wanaka. Lake Wanaka Trust was also established by the Guardians to provide funding for the protection of deep alpine lakes from invasive species. The Guardians of Lake Wanaka have provided and offered to support ORC in identifying and managing lake snow; however,

the ORC, according to Robertson (Chairperson of Guardians of Lake Wanaka, personal communication, 2017), has not been forthcoming in accepting the Guardians' help, which has been frustrating for the Guardians. There is a lack of understanding and common foundation between the different organisations—central government, regional and district councils and non-governmental organisations (Drage & Cheyne, 2016). There is a lack of understanding of the threat that lake snow poses to the community and environment, as well as a lack of transparency and support between groups. It would be much more effective and beneficial if the organisations were on common ground and, engaged openly with one another and supported each other through the management and identification process of unidentified organisms.

Summary

The institutional arrangements under the BSA framework and other legislation such as the Conservation Act 1987, Hazardous Substances and New Organisms (HSNO) Act 1996 and Lake Wanaka Preservation Act 1973 are essential to managing invasive species. However, institutional arrangements under the BSA identified in this research do raise some challenges that affect the efficiency of biosecurity management in New Zealand and, in this specific case, within the Otago region. Lack of consistency and coordination between organisations and levels of governance, and lack of funding available for research can affect how well local councils understand, manage and frame freshwater invasive pests in New Zealand. It creates uncertainty about biosecurity risks, particularly consequences for indigenous flora and fauna (Parliamentary Commissioner, 2002). This a continuing problem of in biosecurity management: uncertainty and risk will be discussed in more detail in the next section on risk and uncertainty of invasive species.

6.3 Risk and Uncertainty

Everyday activities involving travel, trade and commuting create pathways for introducing invasive pests into the country and have the ability to create undesirable environmental effects. Proactive approaches, or what Wynne (1992) refers to as precautionary/preventative principles, seek to prevent the environmental risk before it occurs. The precautionary principle is about anticipating and predicting environmental effects—it is based on anticipatory knowledge. Biosecurity management uses a range of proactive and reactive approaches: firstly, reducing the number of invasive species entering by assessing the risk of organisms entering New Zealand, and, secondly, by managing and controlling the invasive pest once it becomes established in New Zealand. However, this proactive approach to identifying biosecurity risk has inherent limitations according to Wynne (1992), science can only define a risk, or uncertainty by artificially “freezing” a surrounding context which may or may not represent reality, being based on conditional knowledge. Science does have the ability to identify

the risk of invasive pests however does not have the capability to identify what invasive pests will be a threat and whether they will become established in New Zealand.

Applying Wynne's uncertainty framework identified in Chapter 3 is applied to the analysis. Wynne (1992) first concept risk, the freshwater scientists understood that the odds of invasive species being introduced into New Zealand were high through the export and import pathways of goods and services, as well as through domestic and international travel. Hence, the risk of an invasive species entering the country and bypassing pre-border controls could be calculated. However, there was uncertainty surrounding the types of species that would be a risk to New Zealand and whether it would become established in New Zealand.

Uncertainty is Wynne (1992) second concept you may know the parameters and therefore uncertainty can be reduced. The analysis demonstrates that with the establishment of lake snow, the ORC found it difficult to determine whether lake snow would pose a threat to lakes, the environment and the community and what it would mean for the future of the lake. It has taken freshwater scientists 12 years to determine the potential origins of lake snow and the possible environmental drivers (climate change, water flea and land use change). Identifying an invasive species, as required under the BSA, is extremely difficult and time-consuming. However, there still remains a deep uncertainty surrounding the full impact that lake snow will have on the composition of the lakes, which brings us to Wynne's third concept: ignorance (Wynne, 1992). Wynne's ignorance concept forms a deep uncertainty that prevents prediction and cannot be reduced by further research. It is simply not possible to identify specific invasive pests that may come into New Zealand and predict the likely undesirable consequences the organism might have on the environment, people and the economy. The BSA would appear to assume it is easy to invoke the regulations when in fact it is really difficult when there is uncertainty about the organism. Scientists' and policy makers' best chance to manage invasive pests is through preventative mechanisms to reduce invasive species from coming into New Zealand, but if the organism becomes established in New Zealand it can be controlled and managed through reactive approaches within national and regional pest-management strategies.

According to Wynne (1992) last concept indeterminacy is embedded with definition of risk and uncertainty. Wynne argues that indeterminacy underlies the construction of scientific knowledge, as well as the social world in which creates environmental risks. In terms of biosecurity, freshwater is an indeterminate system; there are gaps within scientific knowledge and understanding of freshwater systems. Social institutions, scientists and policy makers seek to understand or to formulate assumptions surrounding why the invasive species (lake snow) is in Lake Wanaka and the surrounding lakes, through creating and forging a connection between the current environmental problems and water quality issues that have been affected by land use change and climate change. In this process of

scientific analysis and risk assessment of invasive species in New Zealand, local authorities tend to treat uncertainties as if there is insufficient or limited information. The freshwater scientists recognised the complexity of the freshwater ecosystems such as deep-water lakes in Otago, and understood that there is limited knowledge available on lake snow, freshwater ecosystems, and the effect such invasive pests can have on the ecosystems, especially considering the size of the deep-water lakes. The scientists and ORC assume that the monitoring equipment did not and does not have the ability to accurately identify or record the extent of lake snow in Lakes Wanaka, Wakatipu and Hawea.

Freshwater scientists have high expectations of central and local government to provide adequate time and funding for research, whereas policy makers expect scientists to be able to provide certainty on information before any decision can be made. On the other hand, ORC had unrealistic expectations of scientists and their ability to quickly identify the origins of lake snow, and they used uncertainty as a reason not to take action, which is counter to the precautionary principle.

ORC could not adequately and effectively manage, nor eradicate lake snow, nor reduce its spread in Otago lakes or other lakes in New Zealand (e.g., Lake Coleridge, Canterbury) due to the combination of inadequate scientific information coupled with similarities between lake snow and didymo. In the next section, the overall biosecurity framework will be evaluated.

6.4 Implementation Gaps within the Biosecurity Framework

The biosecurity framework provides a good guideline for pre-border, border, response and readiness and pest-management strategies. According to MPI (2017) pre-border management, border control, and response and readiness methods are the most effective control methods to combat and reduce the ability for invasive species to be introduced into New Zealand. The readiness and response stage deals with biosecurity emergencies (MPI, 2017) and can be effective, but is dependent on how long it takes the authorities to respond. The current funding arrangements for responding to biosecurity emergencies create uncertainties for the biosecurity agencies involved, as there are financial constraints that can affect how well other agencies can respond to biosecurity risks (Parliamentary Commissioner for the Environment, 2002).

Central government is responsible for updating national plans and strategies. These include long-term pest management, and preparation and review of national and regional pest management strategies. Updating and implementing strategies is a slow process because it can often be difficult to identify what needs to be done, what changes will make a difference, or how effective the overall plan is. Central government plans are extremely general and do not refer to specific environmental matters. As a result, the implementation of these broad central government plans is open to interpretation by the various implementation agencies. Different councils have different methods and approaches tailored to their capabilities. Regional councils are responsible for developing and implementing

regional pest management strategies (PMS) under the BSA. Eradicating an established pest under the HSNO is extremely difficult, especially when there is uncertainty surrounding the establishment, eradication or detection of the unwanted pest or new organism. Under the BSA and the HSNO it is often difficult to determine whether a pest has been recently introduced or if the pest is just beginning to spread in New Zealand. Often pests can remain dormant until the right conditions surface (Parliamentary Commissioner for the Environment, 2002), which is what has occurred with lake snow. However, by the time an organism is identified as an invasive species by a regional council, is placed on the MPI unwanted register, and management plans are developed, it is often too late and these invasive species become unmanageable. This research shows that it took twelve years for ORC to identify lake snow as an invasive species and the key scientists involved have stated in a recent media articles that it is now too late to eradicate lake snow. However, they also note that this should be used as an example to improve councils' responses to introduced species (Waterworth, 2017a).

It is extremely difficult to identify biological risk and threats under the biosecurity framework due to the uncertainties surrounding the risk of invasive pests being established in New Zealand. Overall, the implementation of the biosecurity framework at a one regional council level in Otago is not effective. The research illustrated that is not within the Otago Regional council's capacities to identify, manage and control the introduction of an invasive species without the support of central government organisations. There is simply not enough money, time, experienced staff or adequate monitoring technology and equipment available to carry out frequent monitoring and management of invasive species in New Zealand. Science does not have the ability to identify the risk of invasive pests, and whether they will become established in New Zealand. Under these circumstances and with such challenges, Otago Regional Councils do their best to combat the difficult task of managing and eradicating invasive species (such as lake snow) to ensure the environment, community and economy are protected within Otago, New Zealand.

Chapter 7

Conclusion and Recommendations

7.1 Overview

This chapter provides the conclusions and recommendations of this research. The primary research aims and objectives are addressed; the conclusions drawn from theory and theoretical context are discussed; recommendations are identified and lastly future research opportunities are listed.

7.2 Reappraisal of research aims and objectives

The intent of this research was to identify potential 'implementation gaps' that influence the overall effectiveness of the biosecurity framework within the New Zealand context. Otago Regional Council's response to lake snow under the biosecurity framework was used as a case study in this research. The research aim was met by:

1. Investigating the shift in frames and framing of lake snow over time.
2. Reviewing the institutional arrangements and challenges.
3. Examining the risk and uncertainty of researching invasive species.
4. Making recommendations on how planners should deal with challenging biosecurity issues like lake snow.

7.3 Conclusions

Otago Regional Council's response to lake snow was used in a single case-study analysis to provide useful insights into pest management. This research found that how a biosecurity threat such as lake snow is framed can strongly influence regional council's ability to respond and approach invasive pests. An biological risk identified as an occurrence that may have adverse consequences, can be framed in a variety of ways due to different scientific, community knowledge, social institutions, and challenges incorporated in understanding the phenomenon. This research illustrates that there is high uncertainty surrounding biosecurity risks in New Zealand, therefore risk management is an essential process in biosecurity management to reducing uncertainty and biosecurity risk. However, it is argued that risk management is limited because it is based on anticipatory knowledge, which has fundamental restrictions. Risk analysis within pre-border management, border control and inside the border under the Biosecurity Act 1993 framework is essential to exposing biosecurity risks. Reducing biosecurity risks at pre-border and border is the most important stage of pest management, the types of pests that will

be a threat to New Zealand's economy is difficult to anticipate, precautions such as biosecurity checks are implemented to reduce the influx of pests with mail, passengers and shipping. Once an invasive species breaches the border security and identified quickly it can be eradicated however, if not discovered it becomes too difficult to identify, manage, control and eradicate organisms without strong understanding of the causes.

This research identified that Otago Regional Council uncertainty surrounding lake snow and indeterminate freshwater system led to a slow response towards lake snow, there was no evidence suggesting that lake snow would become a problem for the community. Council formulated naïve assumptions surrounding scientific analysis, council assumed that more scientific research would be key to managing lake snow. However, this approach to freshwater pests can have both positive and negative impacts as waiting for strong scientific evidence can lead to profound unmanageable impacts or can allow the regional councils to build an understanding of environment drivers, approaches and the consequences it may have on the environment, allowing the best management strategies and programmes to be implemented by regional council planners. In this case, by the time that lake was identified as a freshwater invasive pest, it was too late to effectively manage and control lake snow as it had already become established in too many lakes in Otago and other lakes in New Zealand. Overall this research demonstrated that the biosecurity framework is difficult to implement at regional planning level, therefore key recommendations and future research have been proposed.

7.4 Recommendations

This research has identified a number of issues with the implementation of the biosecurity framework at regional planning level. These could be addressed, in part, with:

- more support from government in terms of information and funding. The latter could be generated through diverse means such as boat ramp fees.
- better collaboration between governmental and non-governmental organisations, particularly around national and international species databases and information sharing.
- the introduction of a precautionary invasive pest's fund for local government in New Zealand to manage the uncertainty surrounding both the science and responsibility associated with new and potentially invasive species.
- guidelines on identification and regional management regimes for invasive pests.
- acknowledgement of uncertainties and risk of biological invasions and limits in managing invasive pests at a regional level.

The recommendations are essential to improving the in implementation of a biosecurity framework within regional planning in New Zealand.

7.5 Further Research

Further research is also required to improve the management of invasive species in New Zealand. Further research recommended includes refining not only the monitoring and identification of invasive species technology, but also the institutional framework that then manages them. This could be achieved by extending the approach adopted in this research to broaden our understanding of invasive species management in New Zealand.

We could also seek to improve our understanding freshwater ecological natural systems. Improved monitoring technology can ensure that unknown organisms can be screened, sampled and identified by research institutes such as Landcare Research. Improved understanding of freshwater ecological natural systems can lead to an increased understanding in the pressures that increase pests to become establishes and outcome, the effect it may have on the ecosystem. Invasive species are a threat to the economy, environment and community, therefore it is essential that there is an effective framework in place for biosecurity management in New Zealand, to ensure that planners within local authorities are able to competently respond to invasive species within their region.

Appendix A

Interview Questions

A.1 Adam Uytendaal, Freshwater Scientist at Otago Regional Council

Adam Uytendaal an ORC water quality scientist was contacted via email and kindly agreed to participate in a telephone meeting on the 9 August 2017. Uytendaal began working for ORC in 2016, when lake snow was becoming an issue in Otago lakes.

1. When were ORC first aware of lake snow in Lake Wanaka?
2. What changed in 2010 and 2016?
3. What were the key challenges in the management of lake snow?
4. What are the ORC goals for managing lake snow now and in the future?

A.2 Dr Don Robertson, Chairperson of Guardians of Lake Wanaka

Dr Don Robertson has been deeply involved in how lake snow is managed. Robertson is involved in a variety of different organisations such as Guardians of Lake Wanaka, Guardians of Lake Hawea, Lake Wanaka Trust and Upper Clutha Water Group. Robertson was contacted through email and he agreed to have a face-to-face meeting with me on Tuesday 22 August at 1.30 at Lake Hawea Café. Robertson has provided me with a range of information on the organisations' concerns with ORC's approach to lake snow.

1. What is your role as Chairperson of Guardians of Lake Wanaka?
2. How is lake snow perceived by Guardians of Lake Wanaka?
3. Perceptions of ORC approach and response to lake snow?
4. Why do you think influences ORC's slow to response to lake snow?
5. Challenges that Guardians of Lake Wanaka have encountered when dealing with lake snow?
6. What should happen to improve the management of lake snow?

Appendix B

Letters

Robertson has provided me with a number of letters from 2014 to 2017 that highlight the Guardians concerns over the ORC approach to managing lake snow.

B.1 Letter to the Minister for the Environment

On the 2 March 2016, Robertson sent a letter to Dr Nick Smith regarding his concern about Otago's deepwater lakes and he provided recommendations for the Ministers for the Environment, Primary Industries, and Conservation.

Robertson expressed the Wanaka community's growing concern over the changes in Lake Wanaka water quality due to the that impact lake snow was having on recreation, household appliances and the unknown effect on lake ecosystems. Robertson highlighted ORC's statutory role for management of Otago's water. However, he pointed out that ORC's budget constraints and limited staff affect ORC's ability to effectively manage lake snow. The Guardians were not convinced that ORC plan change 6A was sufficient to manage these lakes, it might result in further decline of the water quality. The Guardians feared that a further decline in water quality might reduce local and tourists' perceptions and appreciation of "pristine" lakes, which would result in economic impacts on the region.

The Guardians had offered to work with ORC several times to research and manage lake snow. However, to date, ORC had not responded to the Guardians' offer. Therefore, the Guardians set up Lake Wanaka Trust to gain traction on these issues and facilitate funding for action on lake snow research and management.

The Guardians recommended that the ministers acknowledge the growing concern about water quality in Lake Wanaka, assign appropriate MfE staff experts to work with the Guardians and, lastly, that they set aside funds to develop an Otago deepwater lakes-management plan, a long-term research and monitoring programme and a regularly reviewed lakes-management decision-making process.

B.2 Letter to the Otago Daily Times

On 12 June 2017 Don Robertson sent a letter to the editor of the *Otago Daily Times* regarding a comment made by Stephan Woodhead, ORC chairperson, to an ODT journalist about “it not being Otago rate payers’ responsibility to fund monitoring for university studies”.

12 June 2017

The Editor,
Otago Daily Times,
PO Box 181,
Dunedin 9054

Otago's alpine lakes management

ORC Chairman, Stephen Woodhead, was quoted in Thursday's ODT (8 June) as saying: “It is not our role to commit regional ratepayers’ money to fund scientific inquisitions or scientific-focused monitoring for universities to study”. This stunning comment was made in the context of ongoing expressions of public concern about the lack of research for evidence based management for Otago's 3 deepwater alpine lakes. We find Mr Woodhead's comments baffling and worrying. If he sees lakes management based research as “inquisitions”, and the role of ORC as excluding university based analysis of “scientific-based monitoring”, then what hope is there of any management of Lakes Wanaka, Wakatipu and Hawea and their catchments? If we are to avoid their continuing degradation from intensification of urban and rural land-use then how is this going to be achieved in the absence of research based management? Those of us who care about maintaining or enhancing water quality and ecosystem functioning in these alpine lakes and their catchments are deeply concerned at the ongoing reluctance of ORC to meet its statutory responsibilities. ORC should be engaging with all the scientific expertise it can muster if there is to be any hope of preventing both declining water quality and changing ecosystem function in these lakes.

Dr Don Robertson

Chair, Guardians of Lake Wanaka.

PO Box 93
Wanaka

References

- Reddish, A. L (2015) Sink or swim? A planner's predicament in a changing Christchurch (Honours Dissertation, Lincoln University, 2015). Retrieved from <http://researcharchive.lincoln.ac.nz/handle/10182/6832>
- Bardwell, L. V. (1991). Problem-Framing: A perspective on environmental problem-solving. *Environmental Management* 15(5), 603-612.
- Biosecurity Act 1993. Wellington, NZ: New Zealand Parliament
- Biosecurity New Zealand. (2006). *Risk Analysis Procedures (Version 1)*. Ministry of Agriculture and Forestry. Retrieved from http://www.piat.org.nz/uploads/PIAT_content/pdfs/risk-analysis-procedures.pdf
- Brugnach, M., Dewulf, A., Pahl-Wostl, C. and Taillieu, T. (2008). Toward a relational concept of uncertainty: knowing too little, knowing to differently, and accepting not to know. *Ecology and Society* 13(2),30
- Cook, D., Liu, S., Aurambout, J. P., Villalta, O., Kriticos, D., Edwards, J., ... Lowell, K. (2012). *Communication Uncertainty in Biosecurity Adaption (Final Report)*. Bunbury, WA: Cooperative Research Centre for National Plant Biosecurity.
- Cook, M. (2016, September 8). The algae and the flea: Wanaka raises biosecurity concerns. *Stuff*. Retrieved from <http://www.stuff.co.nz/national/84043014/the-algae-and-the-flea--wanaka-raises-biosecurity-concerns>
- Dewulf, A., Barbara, G., Putnam, L., Lewicki, N. A., Bouwen, R & van Woerkum, C. (2009). Disentangling approaches to framing in conflict and negotiation research: A meta-paradigmatic perspective. *Human Relations* 62 (2), 155-193
- Drage, J & Cheyne, C. (2016). *Local Government in New Zealand: Challenges and Choices*. New Zealand, Dunmore Publishing Limited.
- Flynn, L. (2016, August 16). *Didymo making South Island river fish smaller, researcher say*. Retrieved from <http://www.stuff.co.nz/environment/83218779/didymo-making-south-island-river-fish-smaller-researchers-say>
- GIA. (2017). *The Biosecurity Act 1993 and the GIA Deed*. Retrieved from <http://www.gia.org.nz/About-GIA/The-Act-and-Deed>
- Gibb, J. (2017, April 7). Lake snow algae research 'priority'. *Otago Daily Times*. Retrieved from <https://www.odt.co.nz/regions/wanaka/lake-snow-algae-research-%E2%80%98priority%E2%80%99>
- Goldson, S. L & Suckling, D. M. (2003). *Defending the Green Oasis: New Zealand Biosecurity and Science*. New Zealand: *New Zealand Plant Protection Society*.
- Guardians of Lake Wanaka. (2013, March 12). Lake Wanaka – For better or Worse? Planning

- for the future. Seminar hosted by the Guardians of Lake Wanaka.
- Hazardous Substances and New Organisms Act 1996. Wellington, NZ: New Zealand Parliament
- International Society for Diatom Research. (21-26 August, 2016). *24th International Diatom Symposium*. Québec, Canada: International Society for Diatom Research
- Johnston, C. (2010, April 17). Scientist far from Wanaka algae secret. *Southland Times*, p. 10.
- Kilroy, C and Robinson, K. (2017). *Testing “Check, Clean, Dry” decontamination procedures: Trails on “Lake Snow” (Lindavia intermedia)*. Christchurch, NZ: National Institute of Water & Atmospheric Research Ltd
- Lake snow discovered in Hawea as algae spreads through southern lakes. (2016, November 4). Retrieved from <http://www.stuff.co.nz/environment/86094005/Lake-snow-discovered-in-Hawea-as-algae-spreads-through-southern-lakes>
- McKenzie-McClean, J. (2016, November). *Lake Snot poses ‘a national problem’ scientist warns*. Retrieved from <http://www.stuff.co.nz/environment/86816589/lake-snot-poses-a-national-problem-scientist-warns>
- Miller, T. (2017, August). *\$375, 000 for Otago from \$44 million*. Retrieved from <https://www.odt.co.nz/regions/wanaka/375000-otago-44-million>
- Mitchell, C. (2017, July). ‘Lake Snot’ algae now in at least a dozen South Island Lakes. Retrieved from <https://www.stuff.co.nz/environment/94376662/lake-snot-algae-now-in-at-least-a-dozen-south-island-lakes>
- Mitchell, C. (2016, June). *Rare ‘Lake Snot’ mysteriously spreading through South Island Lakes*. Retrieved from <http://www.stuff.co.nz/environment/80814522/Rare-lake-snot-mysteriously-spreading-through-South-Island-lakes>
- Miller, T. (2017, September). *Lake snow link to algae in Seattle*. Retrieved from <https://www.odt.co.nz/regions/queenstown/lake-snow-link-algae-seattle>
- Ministry for Primary Industries. (2016a). *Biosecurity 2025 Protecting to grow New Zealand – Discussion document on proposals for a Direction Statement for biosecurity in New Zealand*. Wellington, NZ: Author.
- Ministry for Primary Industries (2016b). *Funding and Programmes: Check Clean Dry*. Retrieved from <http://www.mpi.govt.nz/funding-and-programmes/other-programmes/campaigns/check-clean-dry/>
- Ministry for Primary Industries. (2017). *Biosecurity*. Retrieved from <http://www.mpi.govt.nz/law-and-policy/legal-overviews/biosecurity/>
- Moir, J. (2017, May). *Ministry for Primary Industries ‘to big’ and putting Manuka honey at risk – Labour*. Retrieved from <http://www.stuff.co.nz/business/farming/9314861/Ministry-for-Primary-Industries-too-big-and-putting-manuka-honey-at-rsk-Labour>
- NIWA. (2014, September). *Didymo in New Zealand: ten years on*. Retrieved from

- <https://www.niwa.co.nz/freshwater-and-estuaries/freshwater-and-estuaries-update/freshwater-update-62-september-2014/didymo-in-new-zealand-ten-years-on>
- Novis, P., Mitchell, C and Podolyan, A. (2017). *Lindavia intermedia, the causative organism of New Zealand lake snow: relationships between New Zealand, North American and European populations according to molecular and morphological data*. Lincoln, NZ: Landcare Research
- Otago Regional Council. (2017a). *Council meetings and agendas*. Retrieved from <http://www.orc.govt.nz/Meetings-Consultations-and-Events/Council-meetings-and-Agendas/>
- Otago Regional Council. (2016). *2016 Council meetings and agendas*. Retrieved from <http://www.orc.govt.nz/Meetings-Consultations-and-Events/Council-meetings-and-Agendas/2016-Council-meetings-and-agendas/>
- Otago Regional Council. (2017b). *Lake Snow*. Retrieved October 27, 2017 from <https://www.orc.govt.nz/managing-our-environment/biodiversity-and-pest-control/pest-control/lake-snow>
- Otago Regional Council. (2009). *Otago Pest Management Strategy*. Dunedin, NZ: Otago Regional Council
- Owen, S, J. (n.d). *Department of Conservation Strategic Plan for Managing invasive weeds*. Wellington, NZ: Department of Conservation
- Parliamentary Commissioner for the Environment. (2002). *New Zealand under Siege Parliamentary: A review of the management of biosecurity risks to the environment*. Retrieved from http://www.pce.parliament.nz/media/pdfs/under_seige_full.pdf
- Leith, P(2009) *Knowing El Nino: Integrating knowledges of managing climate variability in the eastern Australian rangelands*. (PhD Thesis, University of Tasmania, 2009).
- Peel, J. (2005). *The Precautionary Principle in Practice: Environmental Decision making and scientific uncertainty*. Sydney, Austratlia: The Federation Press
- RNZ. (2016, September 12). Lake Snow, 'The new didymo'. *Nine to Noon*. Retrieved from <http://www.radionz.co.nz/national/programmes/ninetoonoon/audio/201815769/lake-snow-'the-new-didymo'>
- Ryder, G. (2017). *Lake Snow Technical Workshop, 20 December 2016: Report on workshop discussions and outcomes, prepared from the Otago Regional Council*. Dunedin, NZ: Ryder Consulting Limited
- Schallenberg, M. (2016). "Lake Snot" spreading among iconic South Island Lakes". *Scoop Media Ltd*
- Schallenberg, M. (2010, September 26). The Unusual Snow of Lake Wanaka. *YouTube* [video file] Retrieved from <https://www.youtube.com/watch?v=94xs81d6w9Q>
- Siegele, L. (2012). *Loss and Damage: The theme of slow onset impact*. Climate Development

- and Knowledge network. Retrieved from <http://loss-and-damage.net/download/6532.pdf>
- Teulon, D.A.J., Boyd Wilson, K.S.H., Holton, A. and Ridley, G.S. (2012). Research on invasive pests and diseases in New Zealand and the law. *New Zealand Plant Protection* 65, 281-288
- Waterworth, K. (2017a, July 8). Lake snow's origins key to way forward. *Otago Daily Times*. Retrieved from <https://www.odt.co.nz/regions/central-otago/lake-snow%E2%80%99s-origins-key-way-forward>
- Waterworth, K. (2017b, June 7). Scientists baffled at lack of lake's 'monitoring buoy'. *Otago Daily Times*. Retrieved from <https://www.odt.co.nz/regions/wanaka/scientist-baffled-lack-lakes-monitoring-buoy>
- Waterworth, K. (2017c, June 8). ORC considering special lake buoy. *Otago Daily Times*. Retrieved from <https://www.odt.co.nz/regions/wanaka/orc-considering-special-lake-buoy>
- Waterworth, K. (2017d, August 23). ORC evaluating lake snow report. *Otago Daily Times*. Retrieved from <https://www.odt.co.nz/regions/wanaka/orc-evaluating-lake-snow-report>
- Waterworth, K. (2017e, June 10). Q&A: Gary Kelliher and Ella Lawton. *Otago Daily Times*. Retrieved from <https://www.odt.co.nz/regions/queenstown/qa-gary-kelliher-and-ella-lawton>
- Waterworth, K. (2017f, September 18). MPI mull show to limit lake snow. *Otago Daily Times*. Retrieved from <https://www.odt.co.nz/regions/wanaka/mpi-mull-show-limit-lake-snow>
- Wynne, B. (1992). *Uncertainty and environmental learning: Reconceiving science and policy in the preventative paradigm*. Lancaster, UK: Butterworth-Heinemann Ltd
- Van Kerkhoff, L. E. & Lebel, L. (2015). Productive capacities: rethinking science-governance relations in a diverse world. *Ecology and Society* 20(1), 14
- Yin, R. (2013). *Case study research: design and methods* (Ed. 5). California: Sage Publications